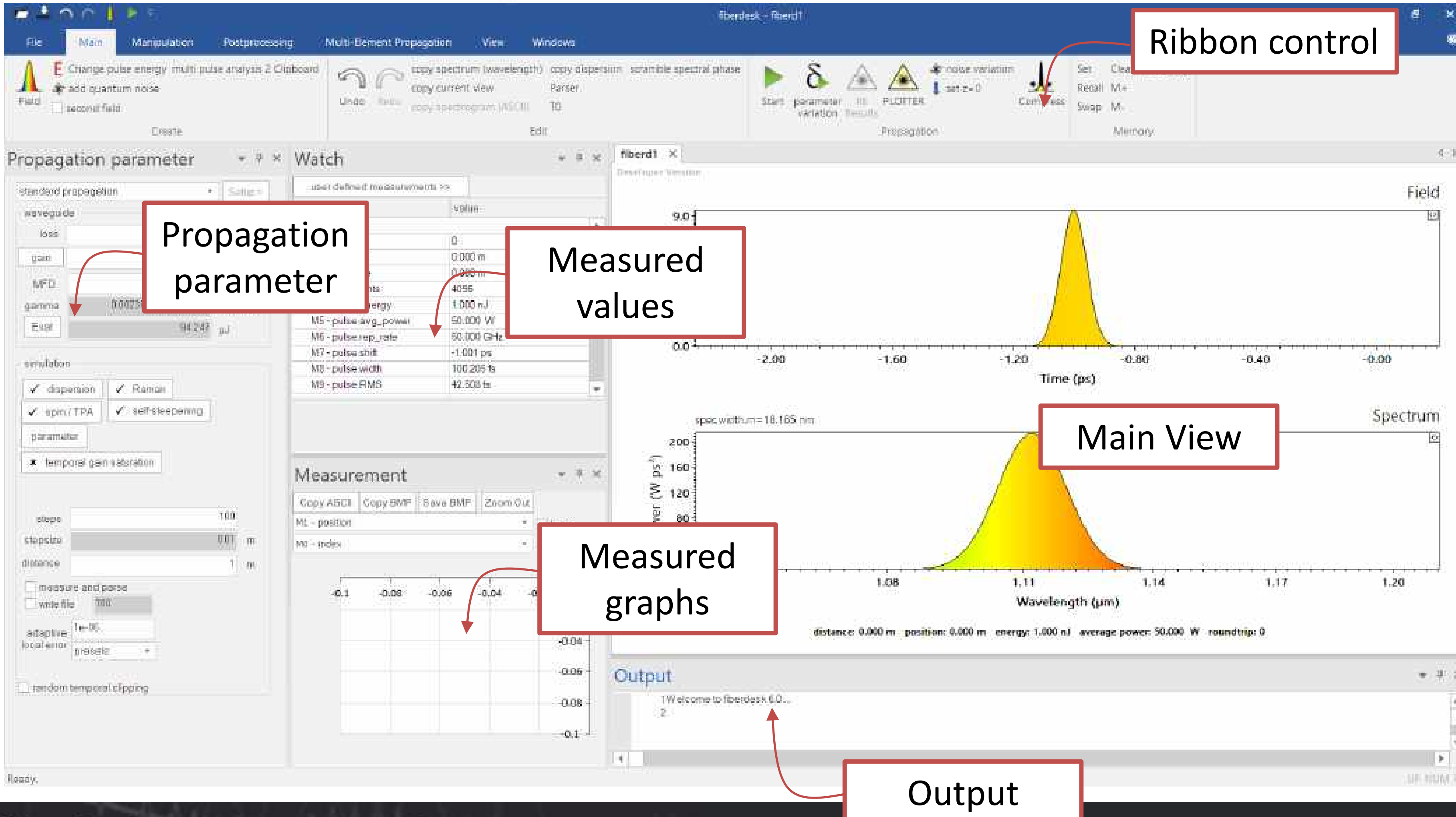
fiberdesk – graphical user interface

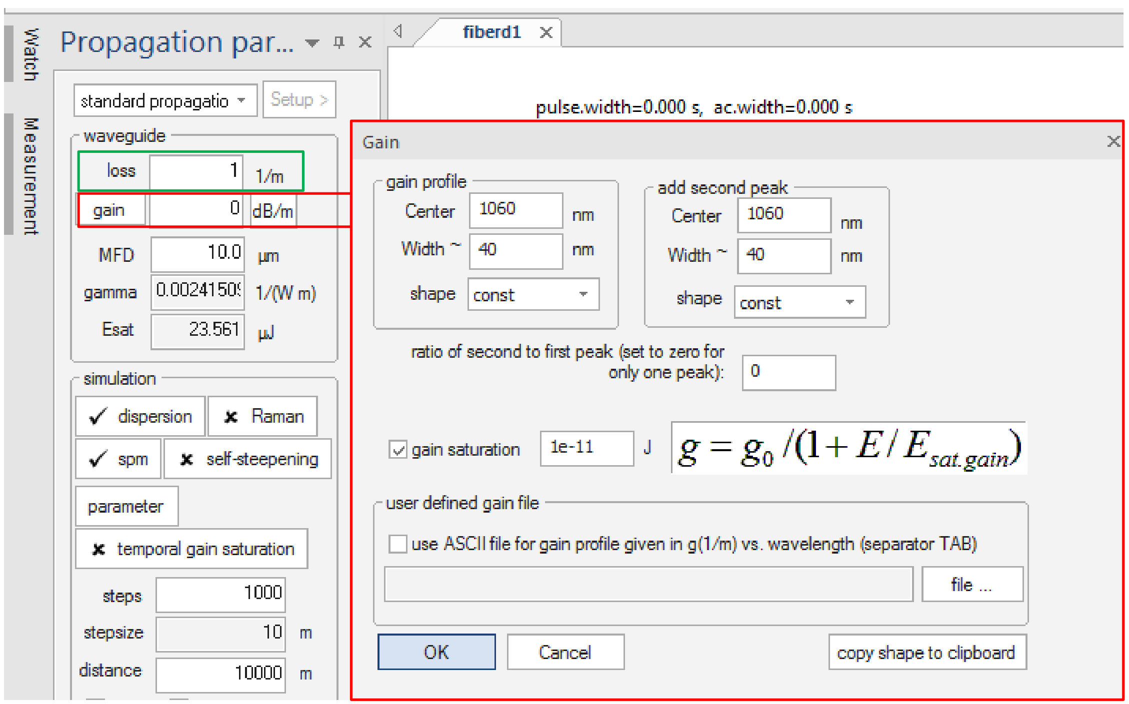
Modern GUI with access to parameter setup and field solution:



fiberdesk – NLSE parameter setup

Parameter access in detail:

$$\frac{\partial A}{\partial z} = -\frac{\alpha}{2}A + \int_{-\infty}^{\infty}\frac{g(\omega)}{2}\tilde{A}(\omega)e^{-i\omega T}d\omega + \sum_{n\ge 1}\beta_n \frac{i^{n+1}}{n!}\frac{\partial^n}{\partial T^n}A + i\gamma\cdot\left(1+i\tau_{shock}\frac{\partial}{\partial T}\right)\left(A(T)\int_{-\infty}^{\infty}R(\tau)\left|A(T-\tau)\right|^2 d\tau\right)$$



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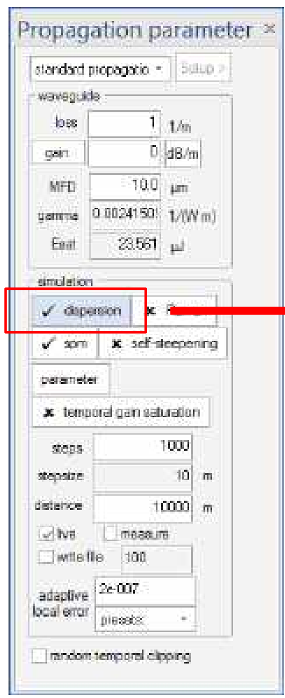

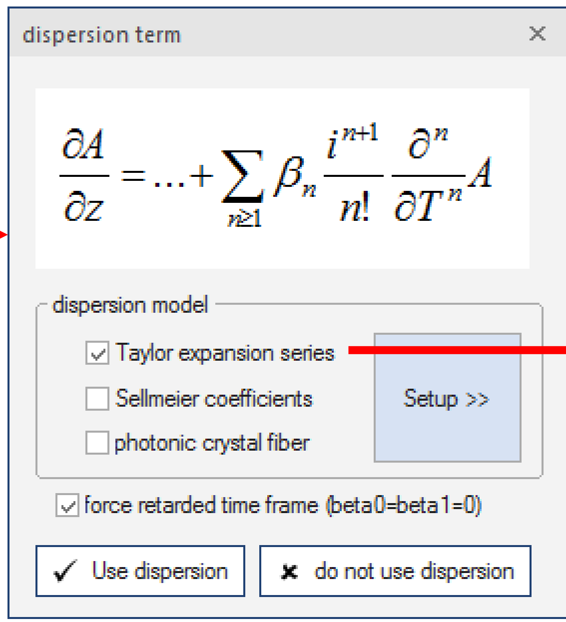

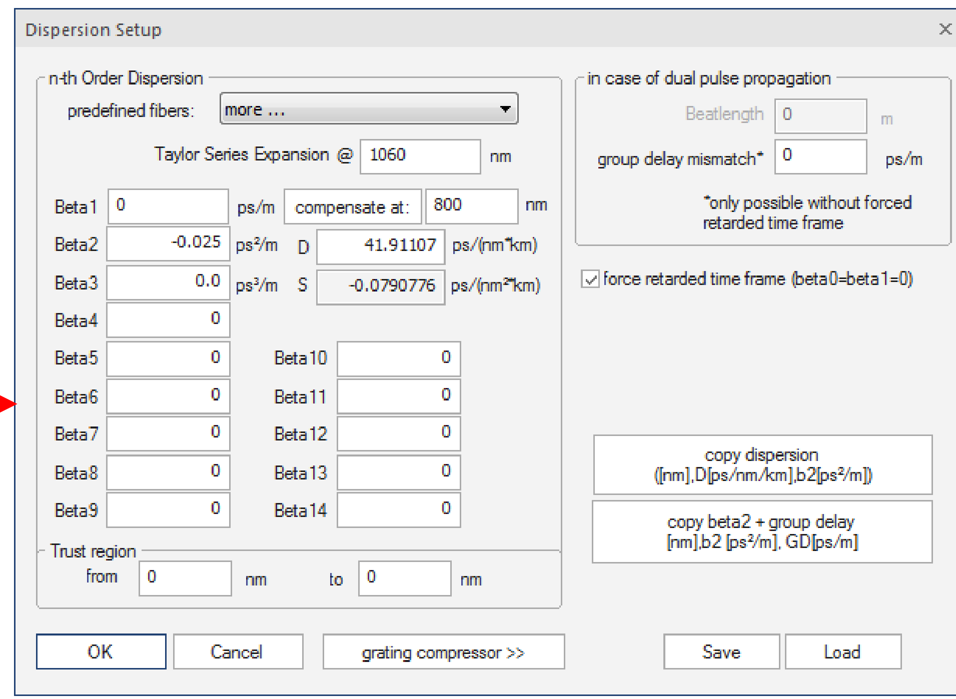

fiberdesk – NLSE parameter setup

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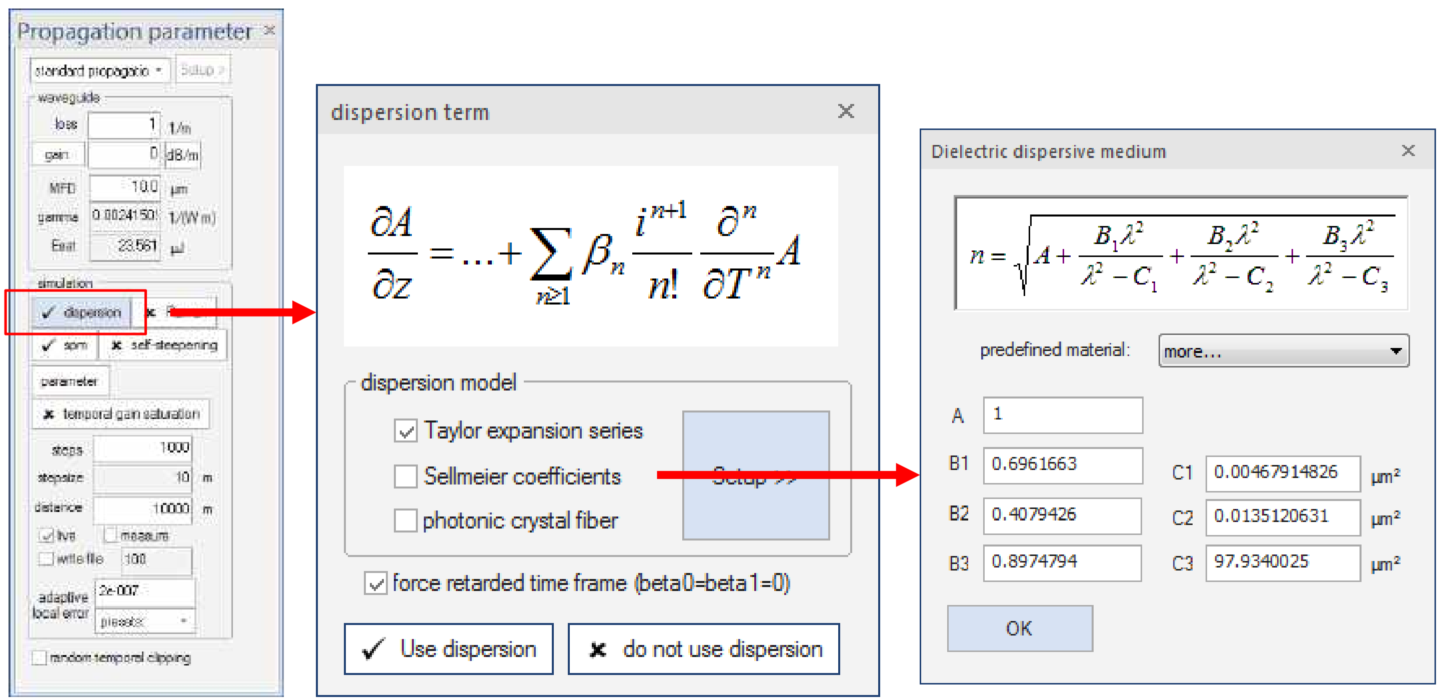

fiberdesk – NLSE parameter setup

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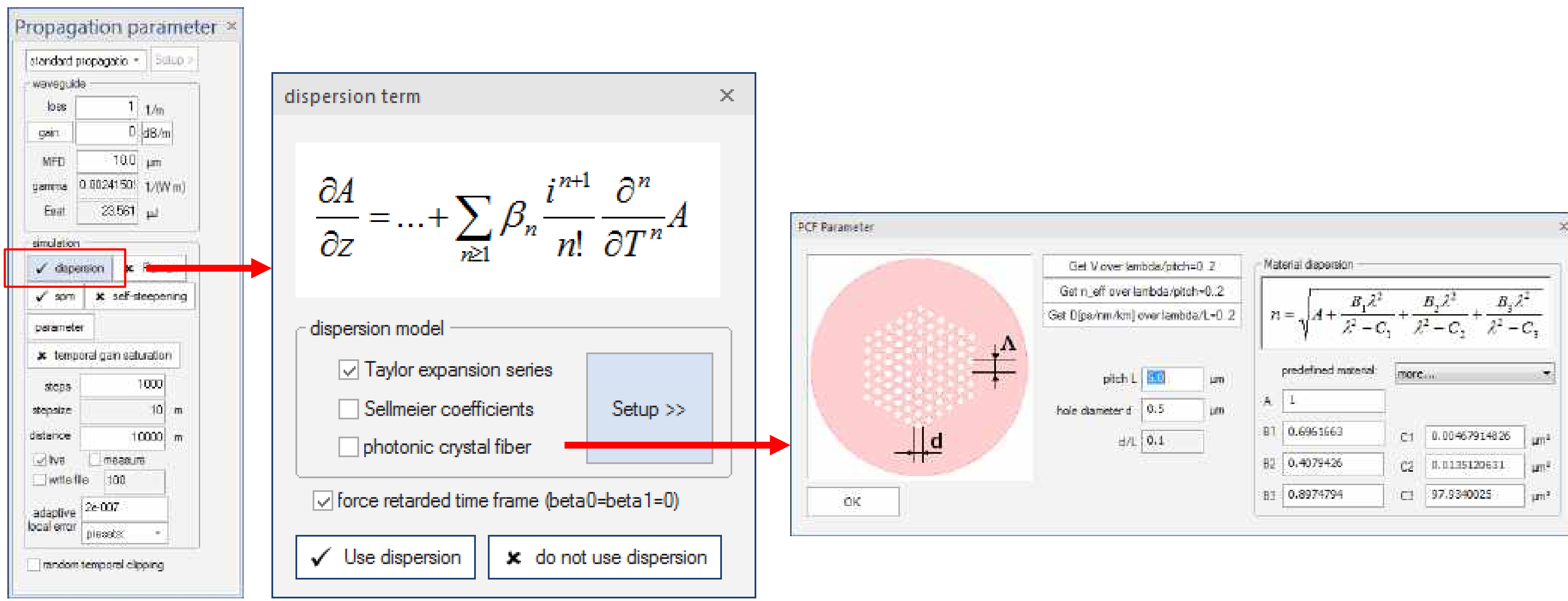

fiberdesk – NLSE parameter setup

Parameter access in detail:

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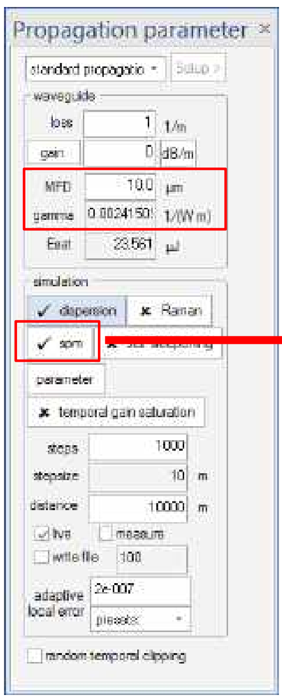

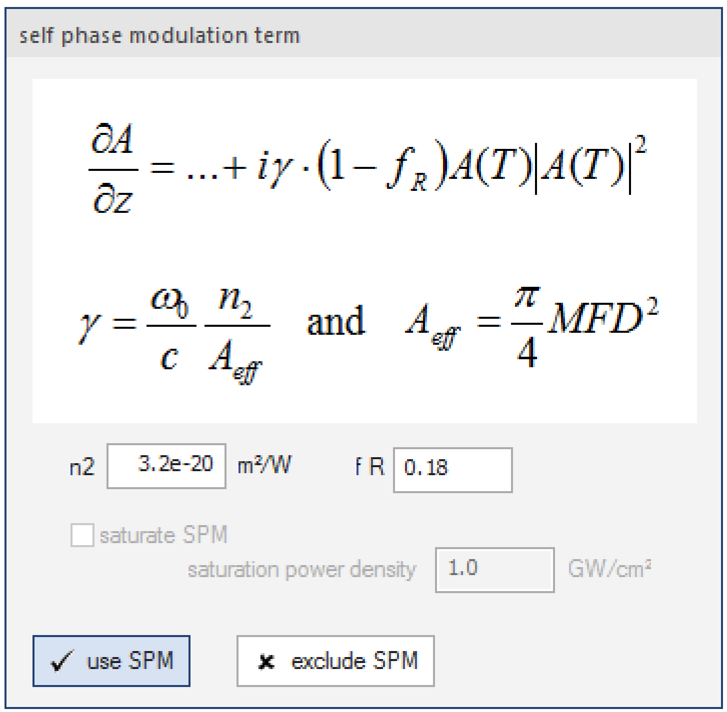

fiberdesk – NLSE parameter setup

Parameter access in detail:

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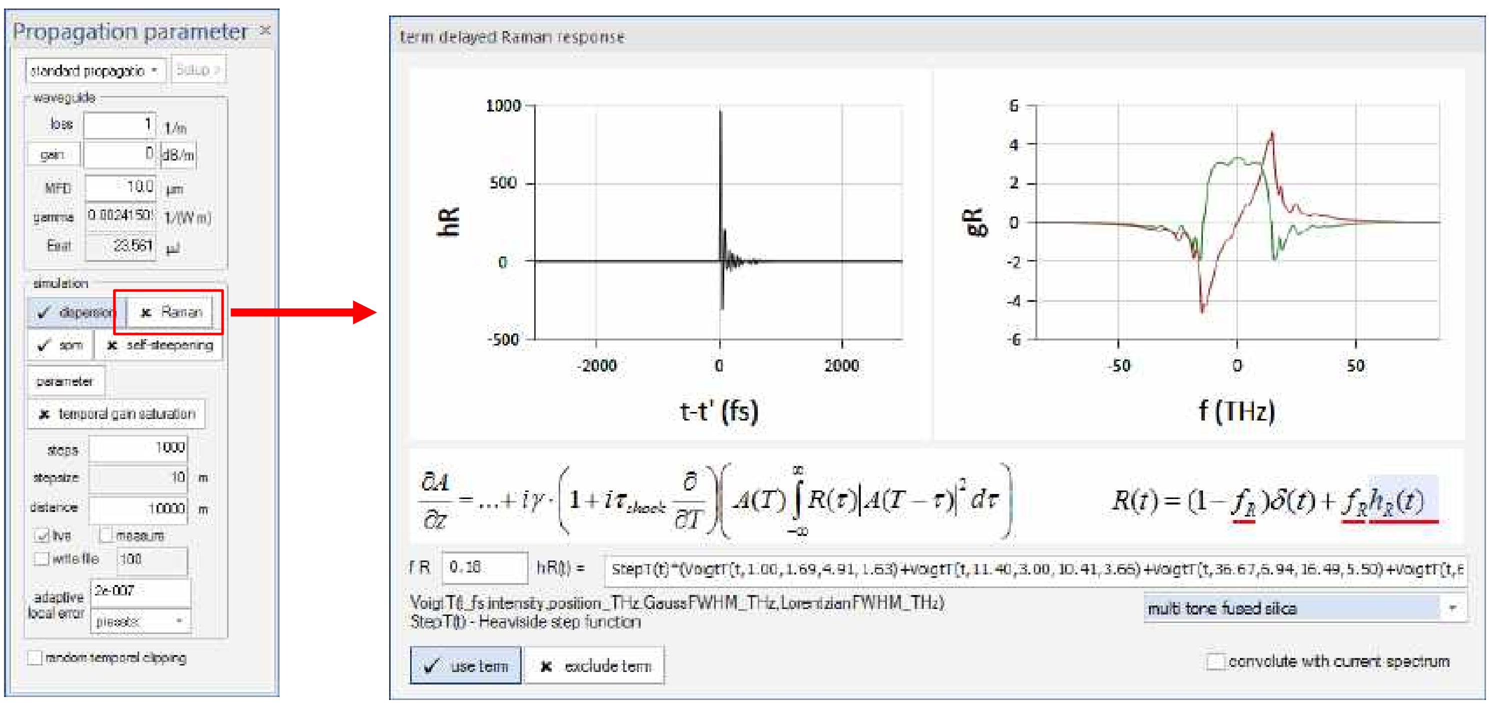

fiberdesk – NLSE parameter setup

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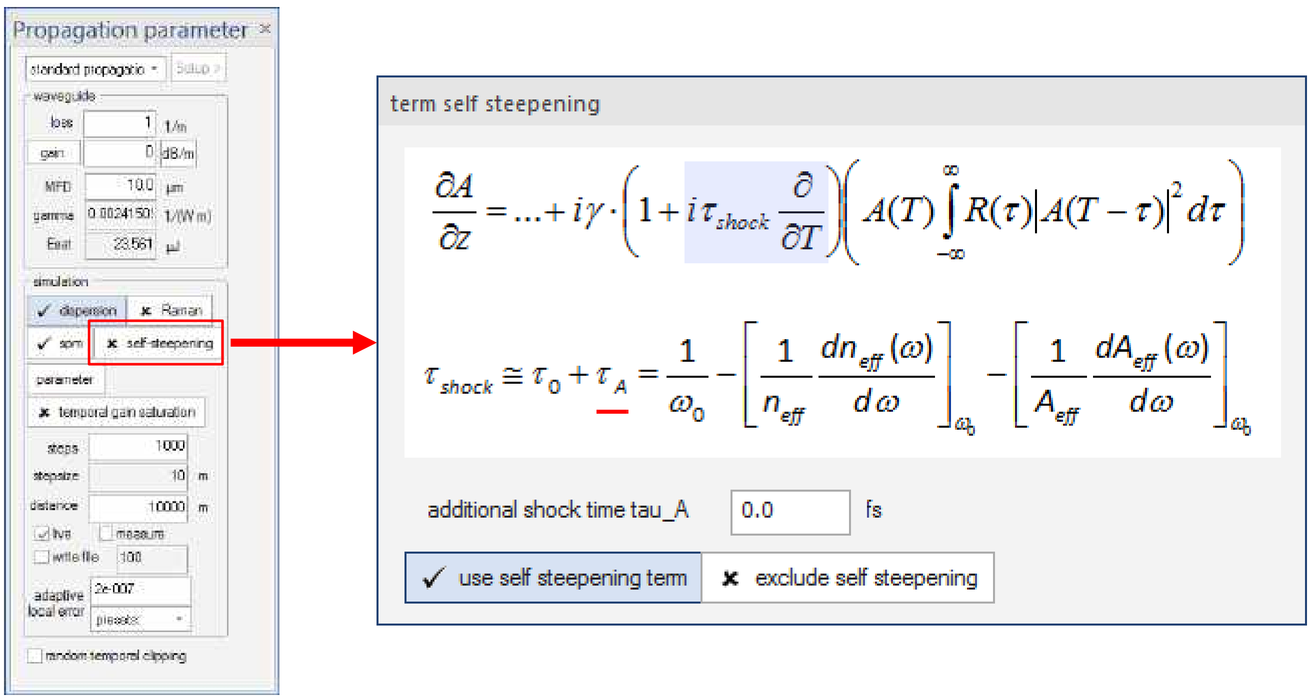
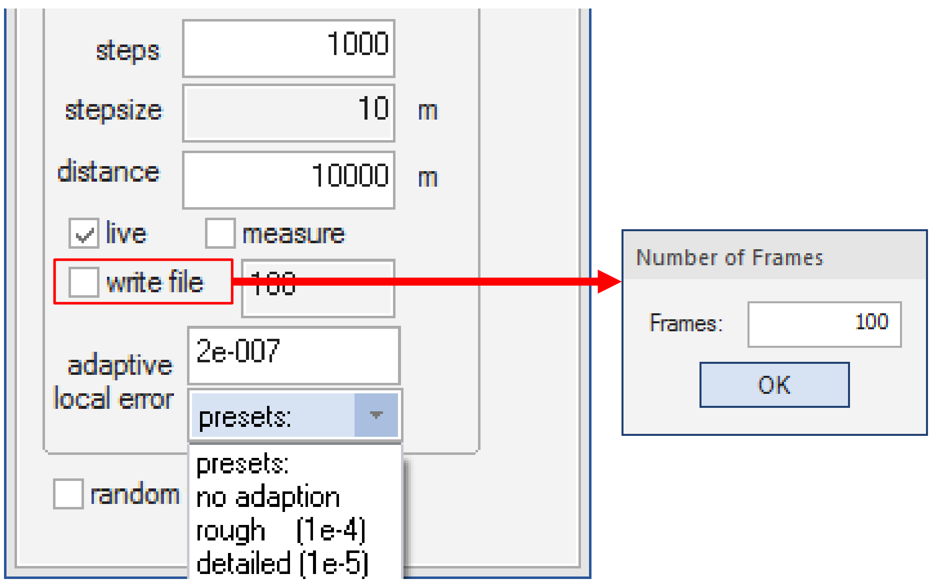


fiberdesk – NLSE parameter setup

Propagation setup:distance, stepsize, numercial accuracy etc.

$$\frac{\partial A}{\partial z} = -\frac{\alpha}{2}A + \int_{-\infty}^{\infty}\frac{g(\omega)}{2}\tilde{A}(\omega)e^{-i\omega T}d\omega + \sum_{n\ge 1}\beta_n \frac{i^{n+1}}{n!}\frac{\partial^n}{\partial T^n}A + i\gamma\cdot\left(1+i\tau_{shock}\frac{\partial}{\partial T}\right)\left(A(T)\int_{-\infty}^{\infty}R(\tau)\left|A(T-\tau)\right|^2 d\tau\right)$$



file contains the initial field plus 100 fields from the calculated propagation for later analysis

file extension: *.BPF

lecture 1

Three simple steps:

(1) create a pulse
(2) choose parameters
(3) press start

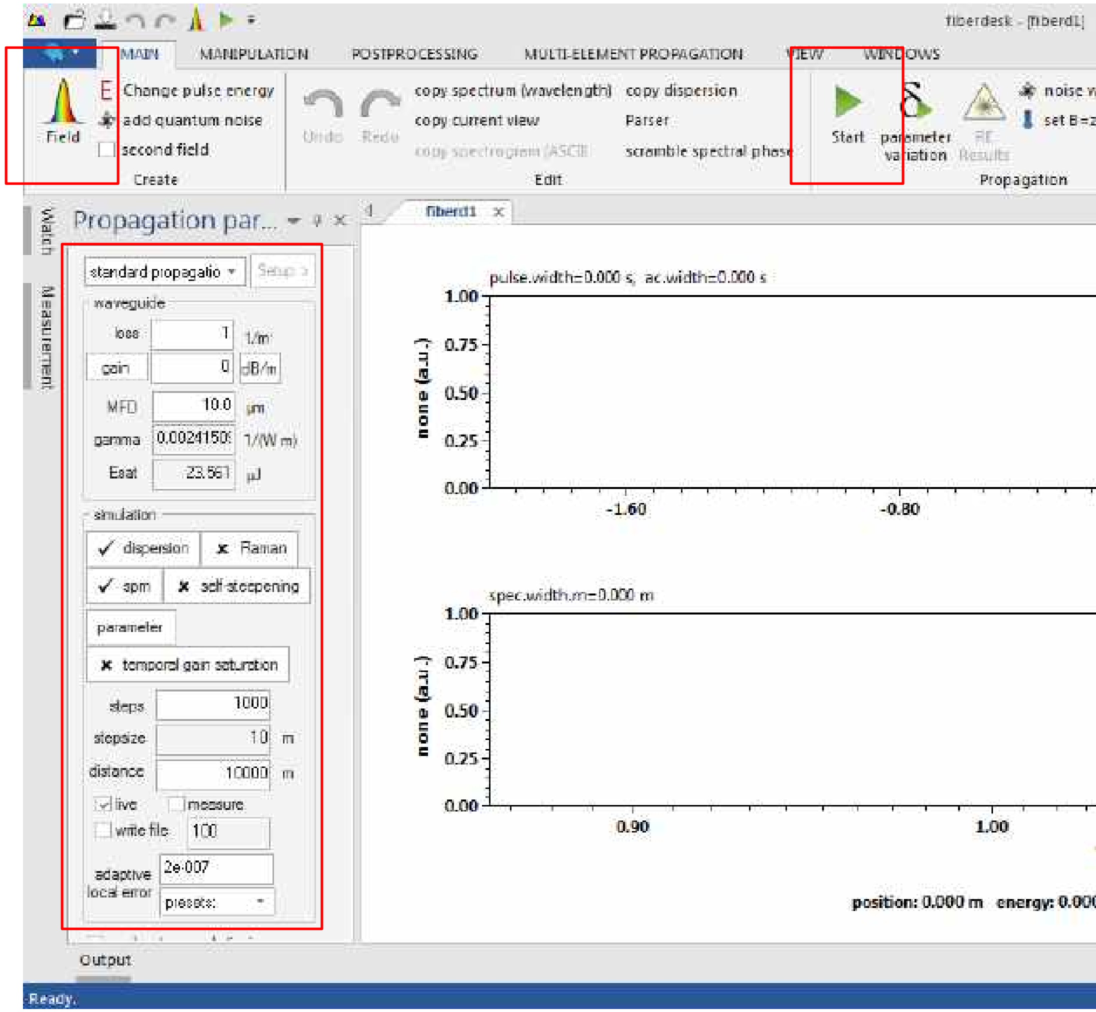
lecture 1

Three simple steps:

(1) create a pulse

(2) choose parameters

(3) press start



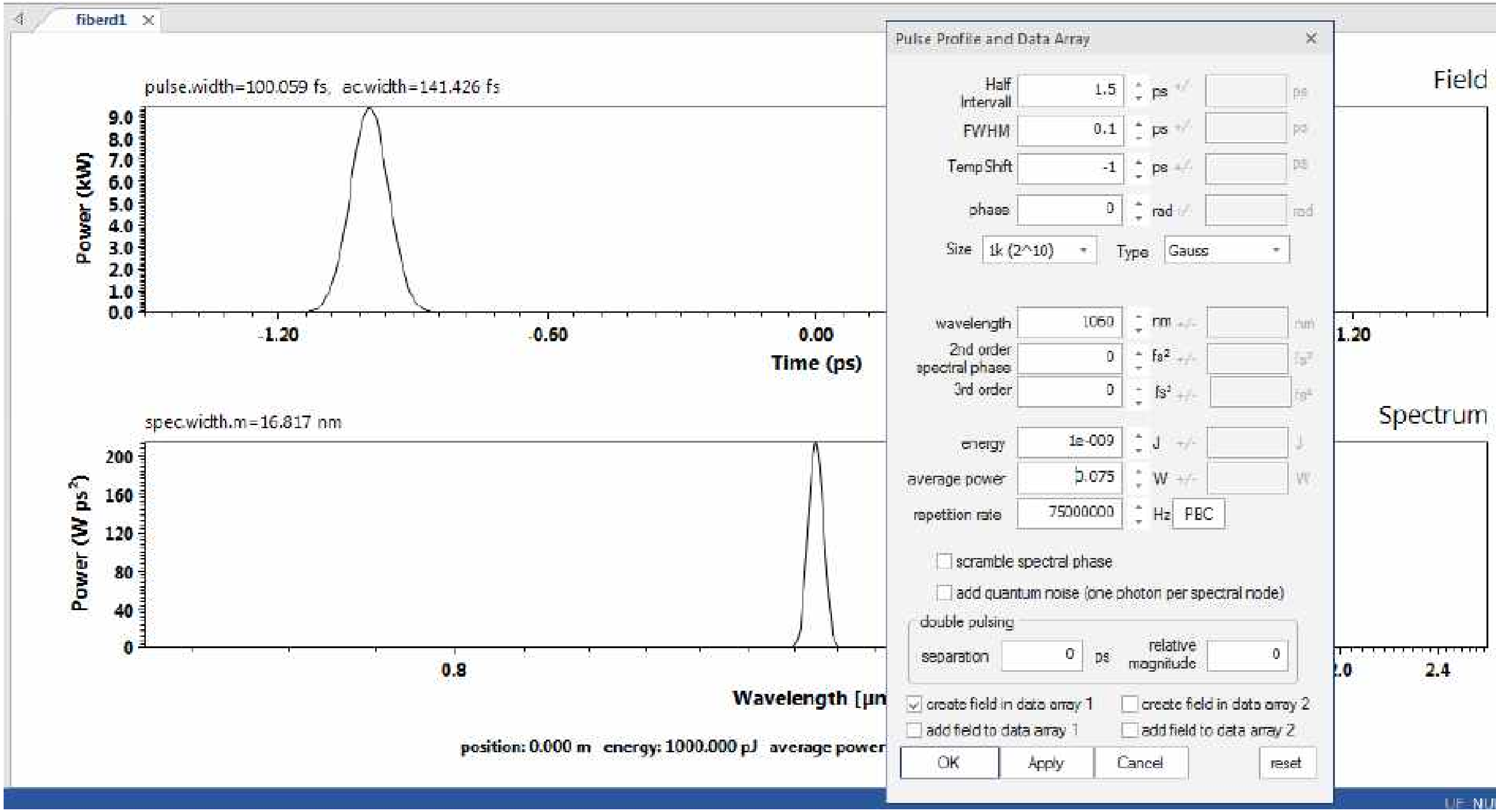
lecture 2

supercontinuum generation, numerical error control and measurements

(1) create a pulse
(2) choose parameters
(3) press start
(4) put result to memory
(5) repeat with higher accuracy
(6) check measurements
(7) noise and coherence

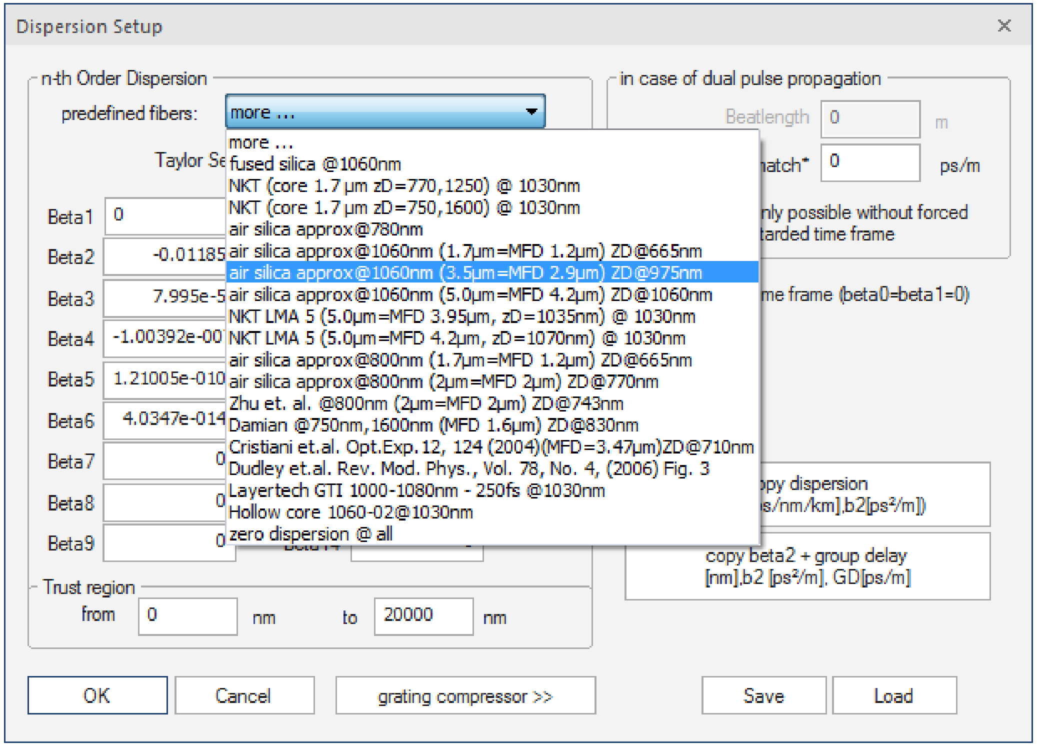
lecture 2

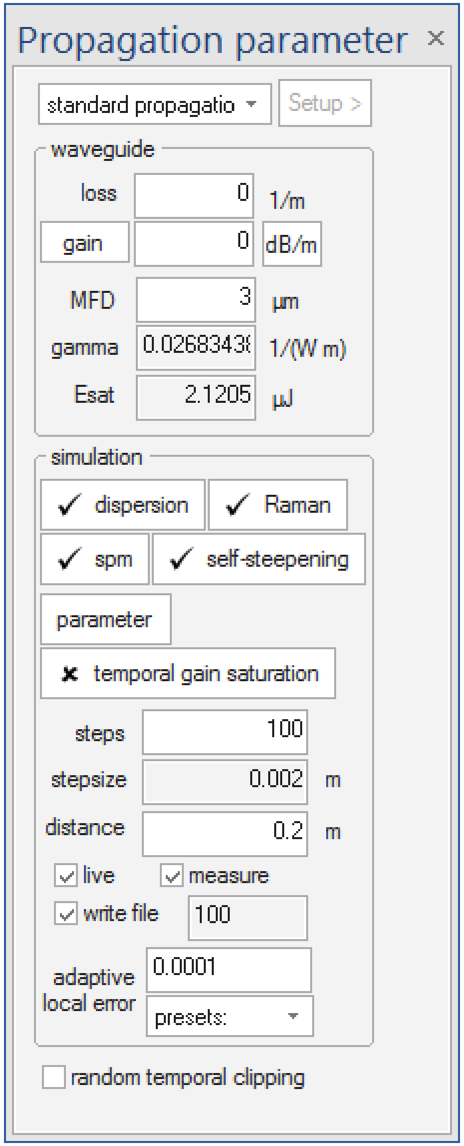
100 fs pulse, temporal windows +/-1.5 ps, 1k datapoints, temporal shift: -1 ps, energy 1 nJ, central wavelength 1060 nm



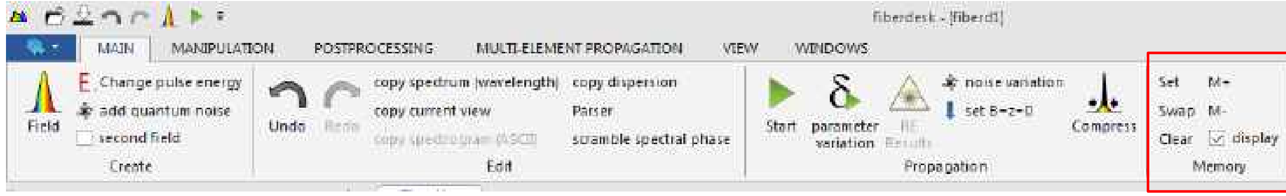
lecture 2

fiber is: NKT-ZD-975 with 2.9 µm MFD, all nonlinear effects considered, Raman response function is simple Lorentz, dispersion preselected.

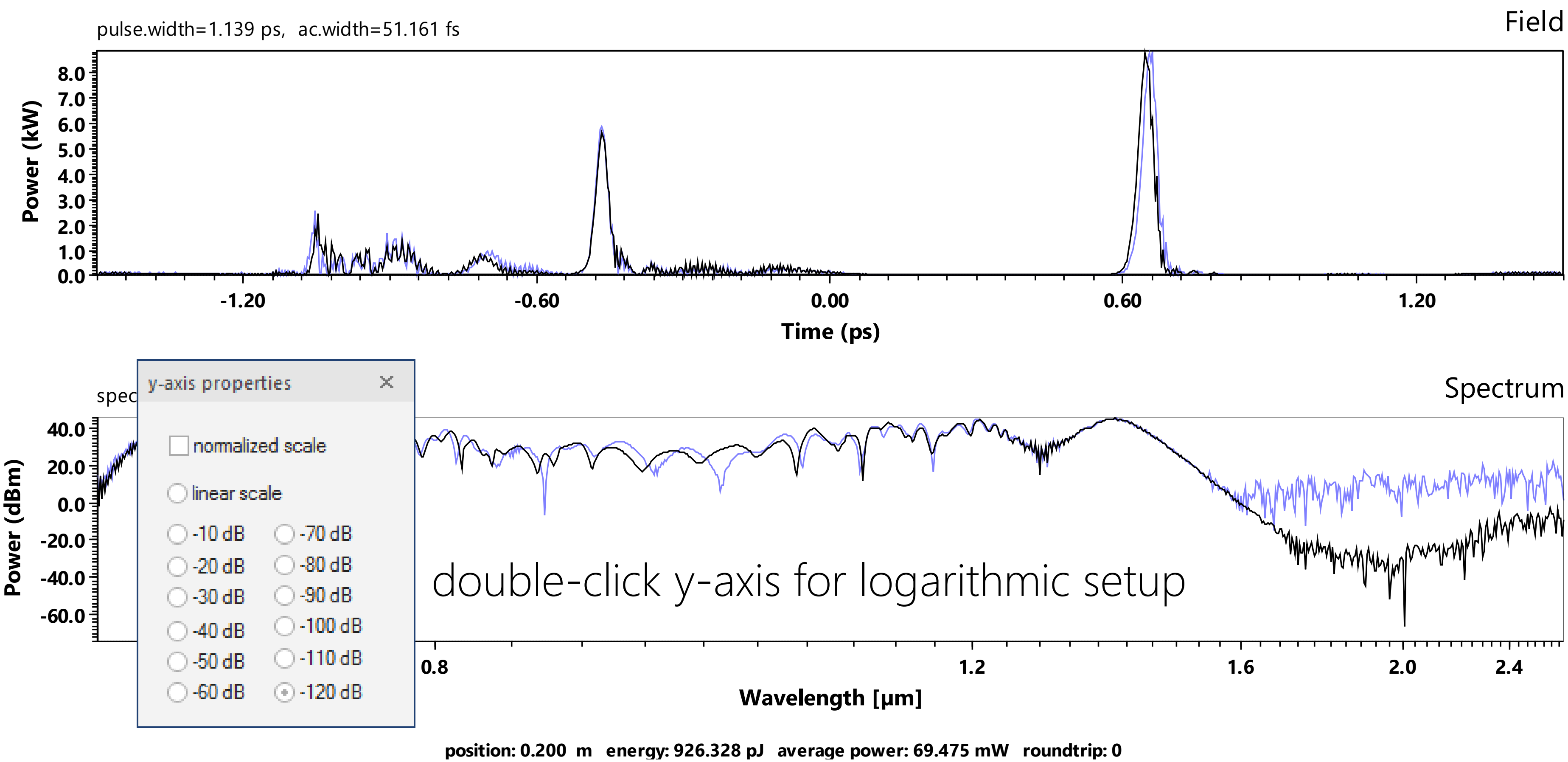




lecture 2



propagate 0.2 m, 100 steps, different accuracy results saved via „memory“>„set“

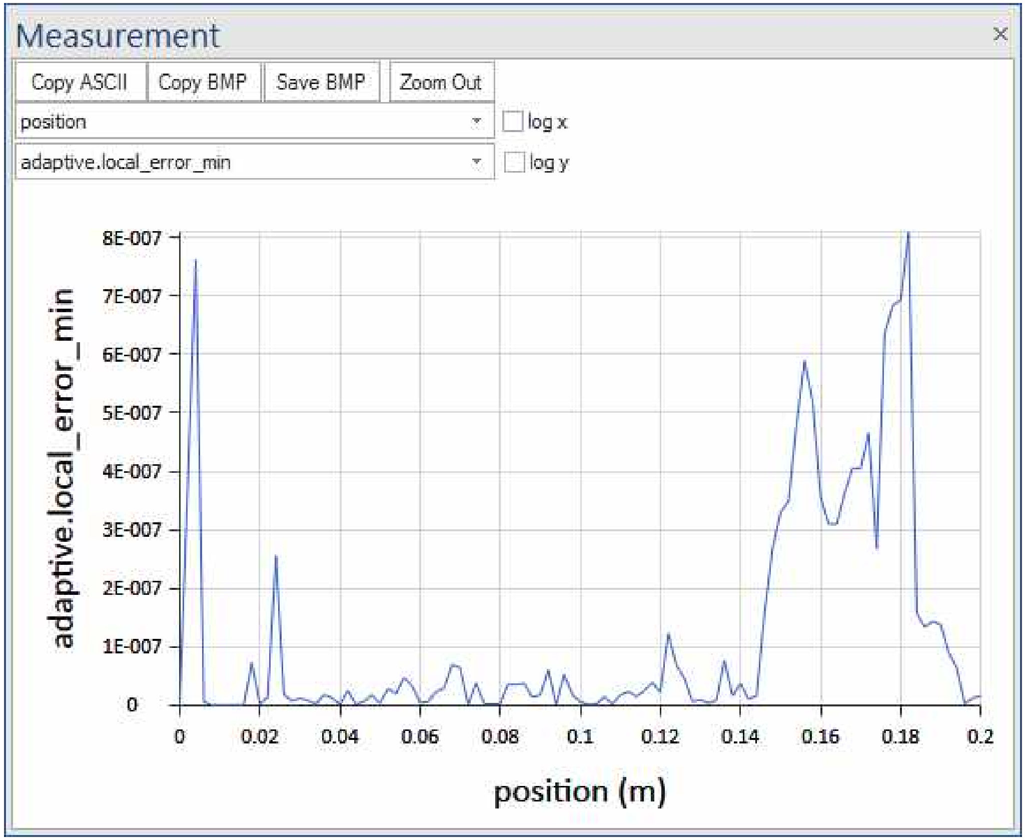


double-click y-axis for logarithmic setup

lecture 2

adaptive algorithm is bounded by local error

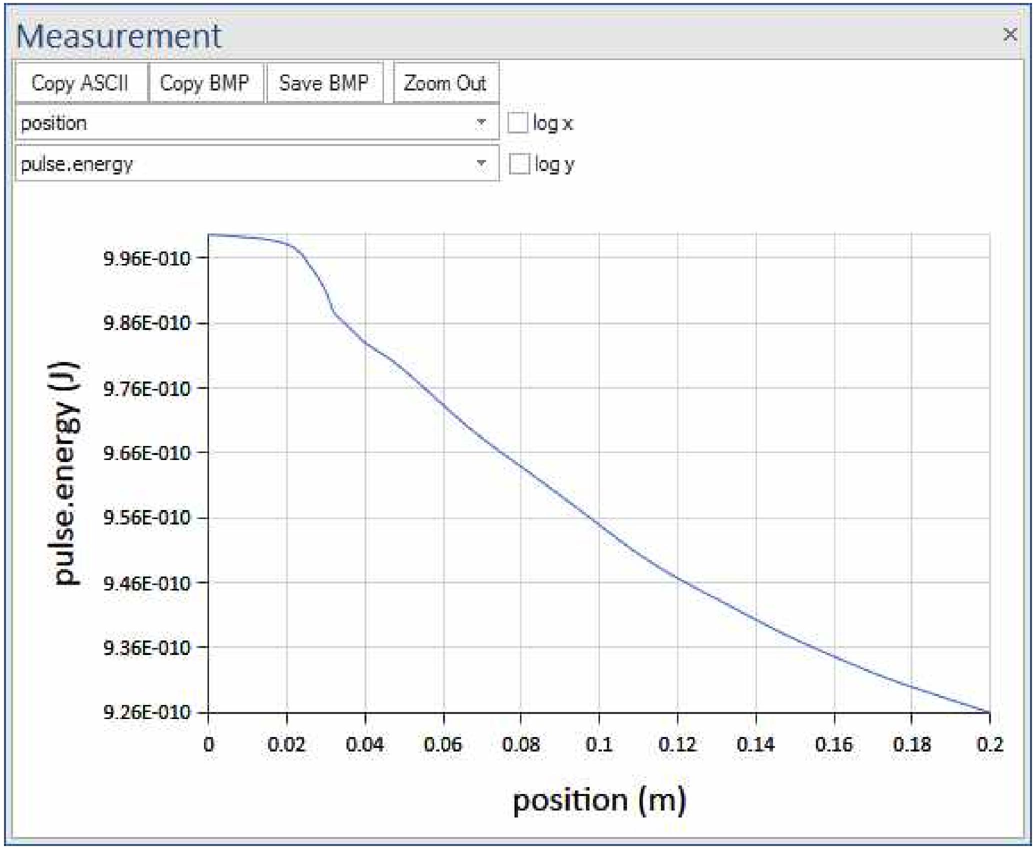
as we measured everything, it can be analysed in the measurement graph



Example: supercontinuum generation with local error <1e-6

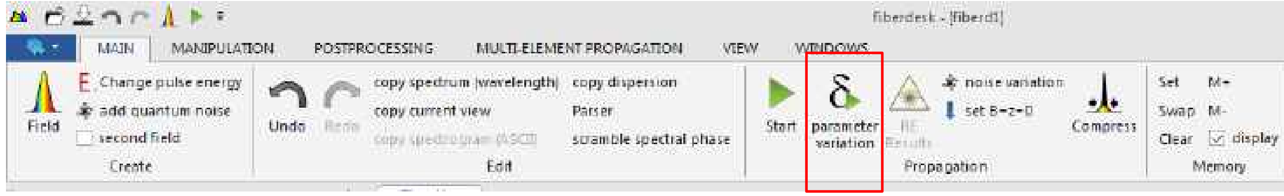
lecture 2

Measurements allow for more detailed analysis:

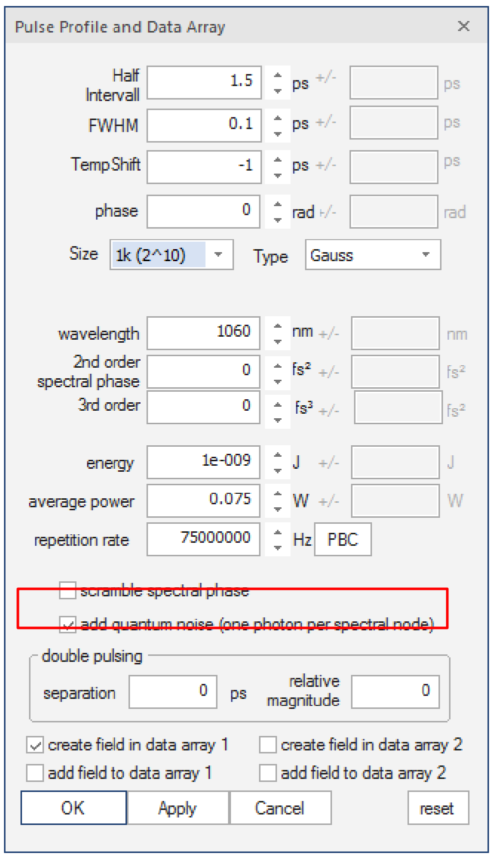


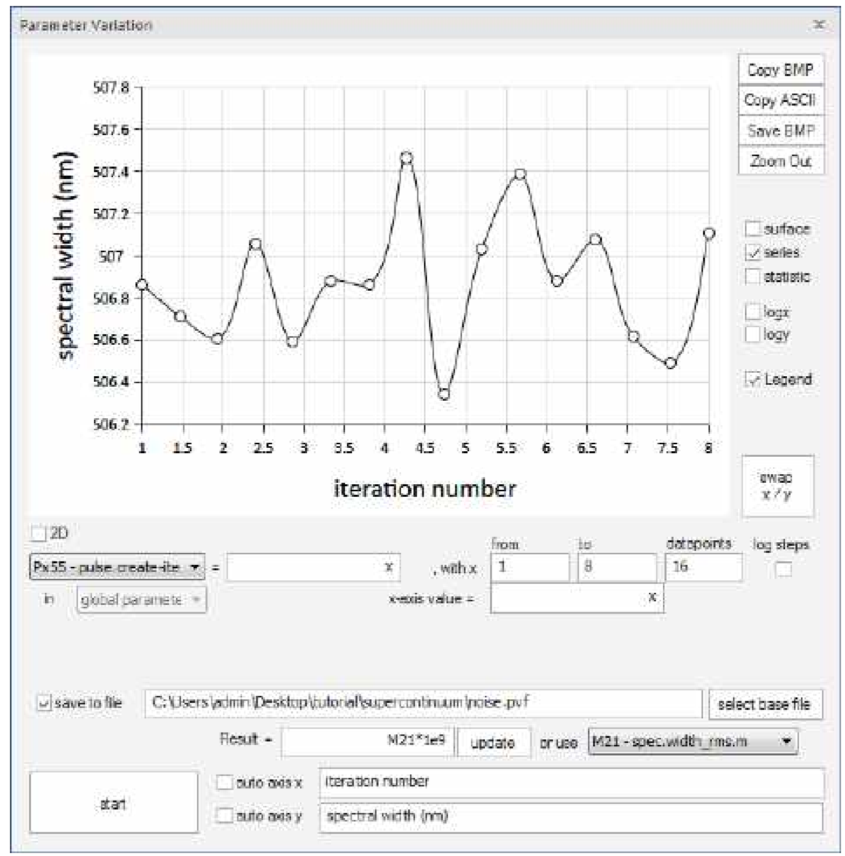
Example: supercontinuum generation energy drop due to intrapulse Raman shift of the soliton, once it is „created"

lecture 2

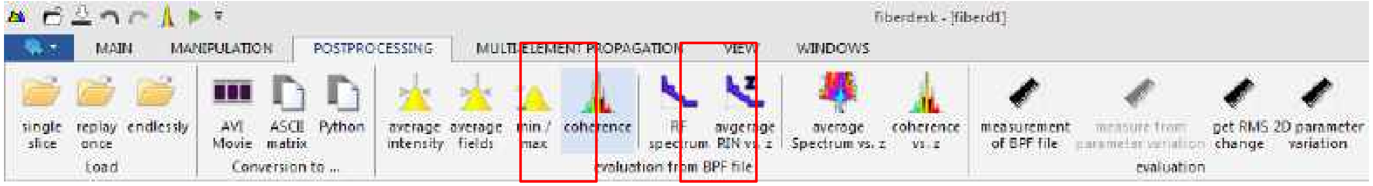


noise and coherence: same starting pulse as before but with quantum noise added, use „propagation“>“parameter variation“ dialog with iterating pulse creation





lecture 2

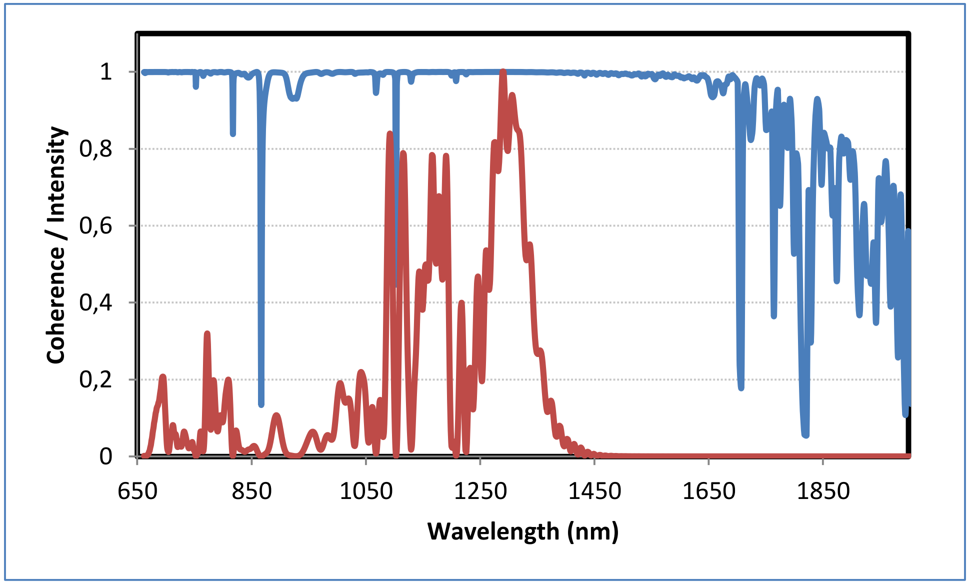


the saved file is now used for average spectrum and coherence calcualation via Postprocessing > coherence

Postprocessing > average intensity

past both results to clipboard and display in e.g. MS Excel

$$\left|g_{12}(\lambda)\right| = \left| \frac{\left\langle E_1^*(\lambda) E_2(\lambda) \right\rangle}{\sqrt{\left\langle \left|E_1(\lambda)\right|^2 \right\rangle \left\langle \left|E_2(\lambda)\right|^2 \right\rangle}} \right|$$



lecture 3

NLSE with gain – simple amplifiers

and

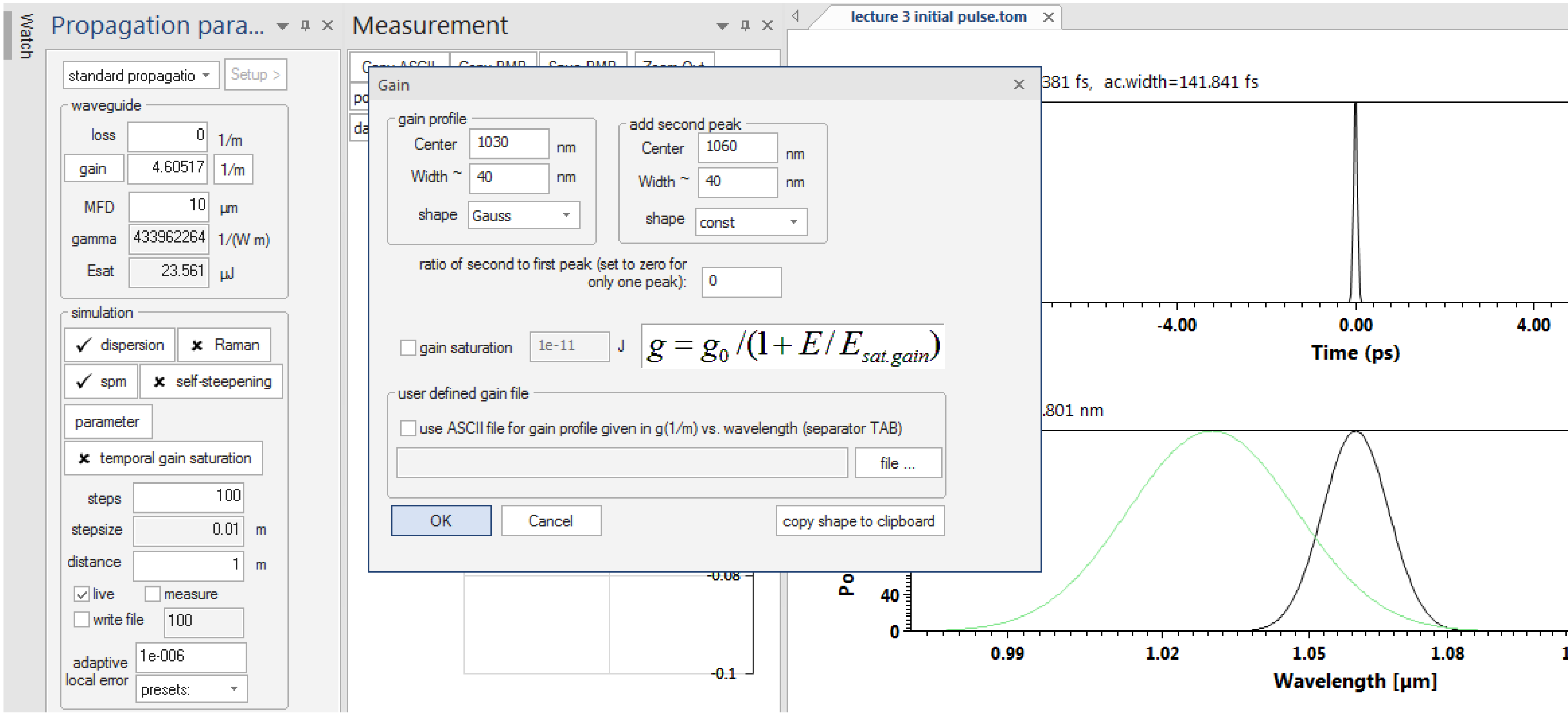
pulse compression

g (1/m) = -ln(Pout/Pin)/L = 4.343 * g (dB/m)

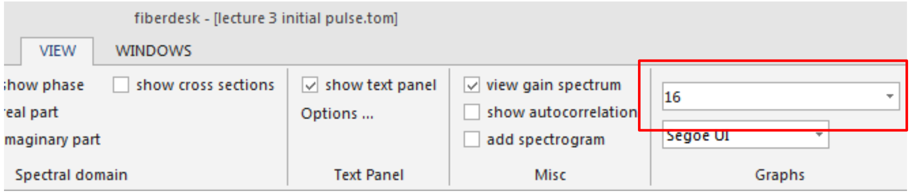
lecture 3

100 fs pulse, +/-10ps window, 1k, 1nJ

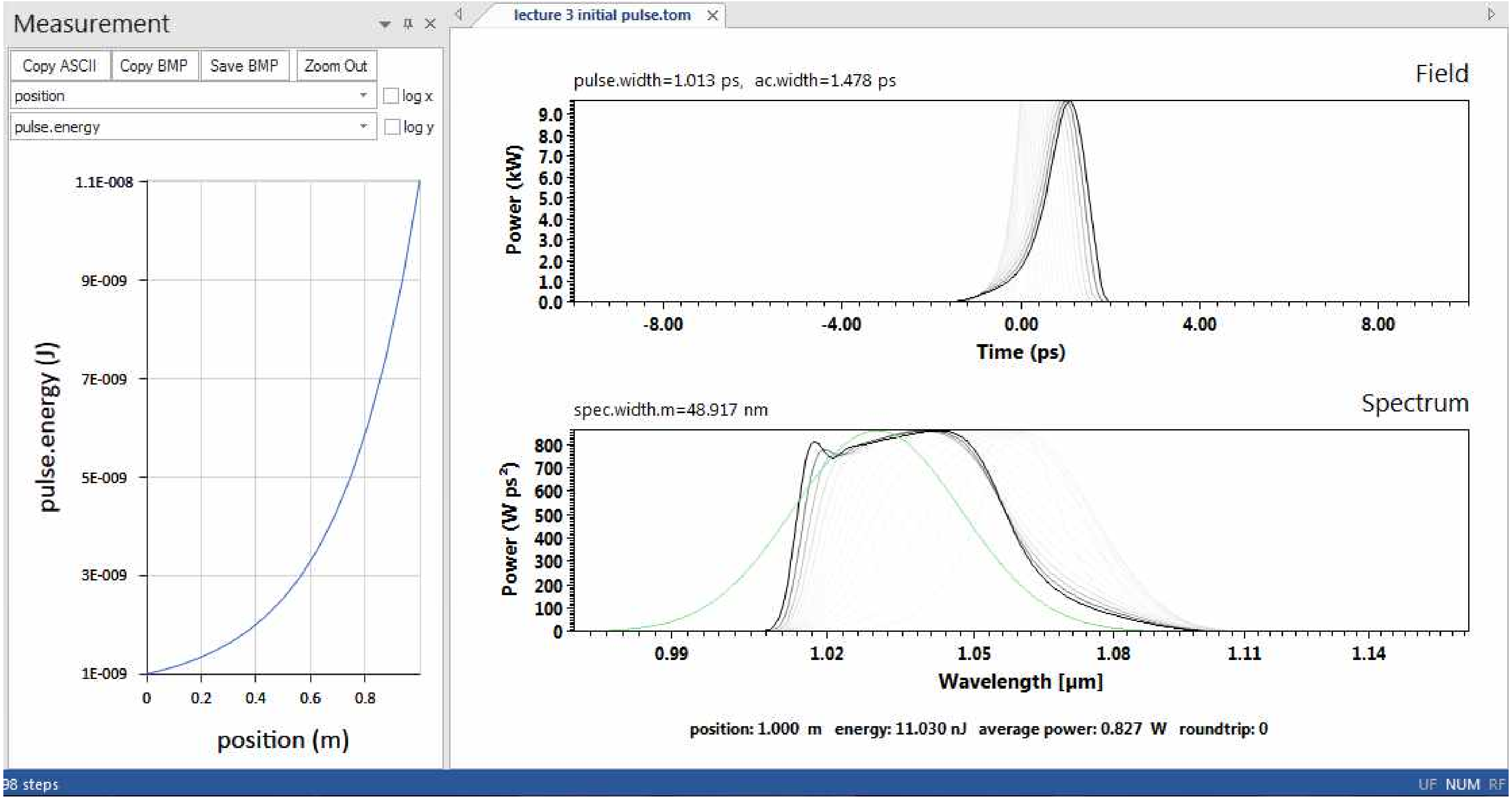
only dispersion and spm, MFD=10 µm, L=1 m, gain=20dB/m, profile: 1030 nm, 40 nm width, gaussian



lecture 3



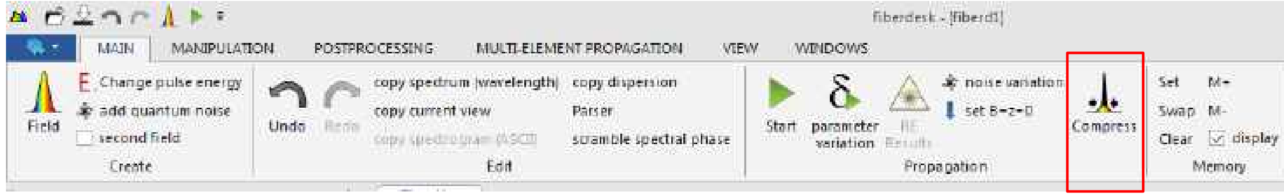
results – with „view“>“persistance“ set to 16 and 16 steps.



lecture 4

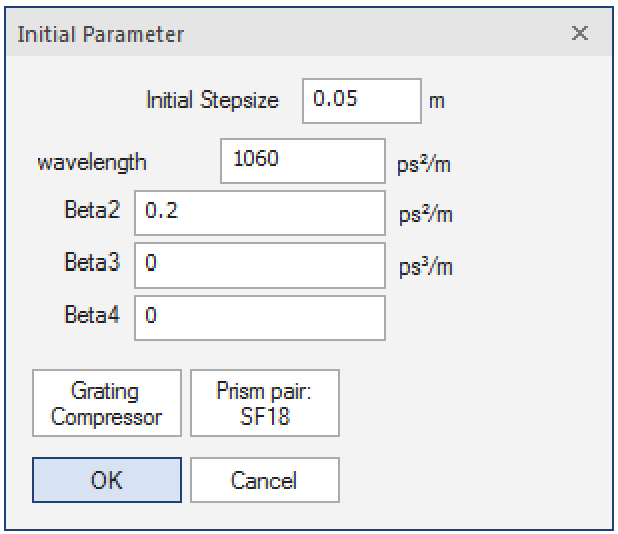
pulse compression

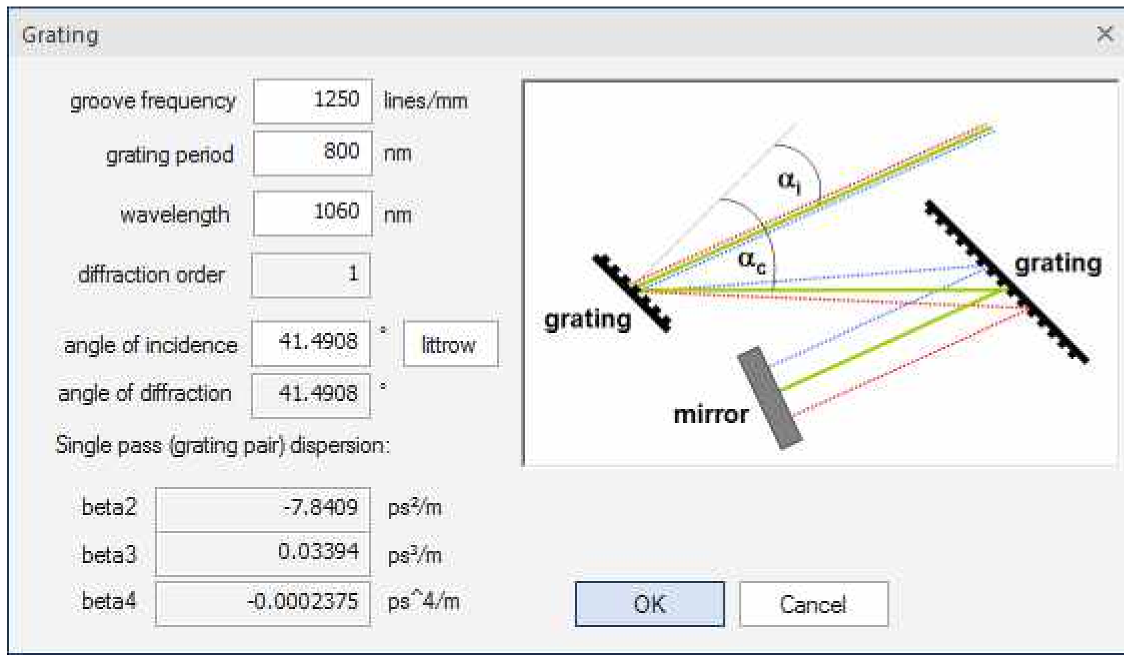
lecture 4



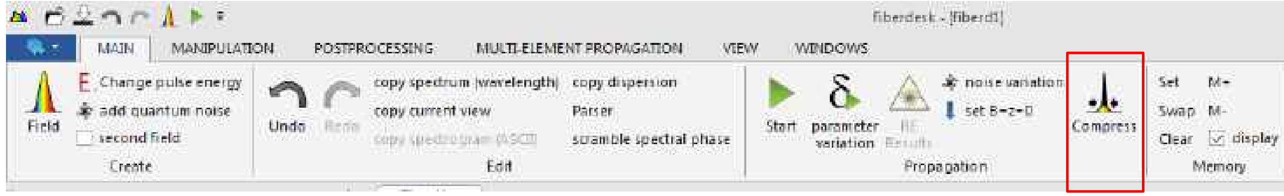
pulse compression

automatic compression minimizes autocorrelation width



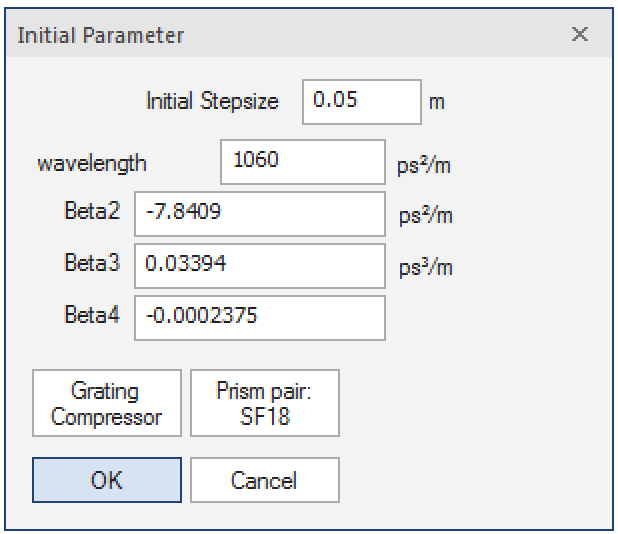


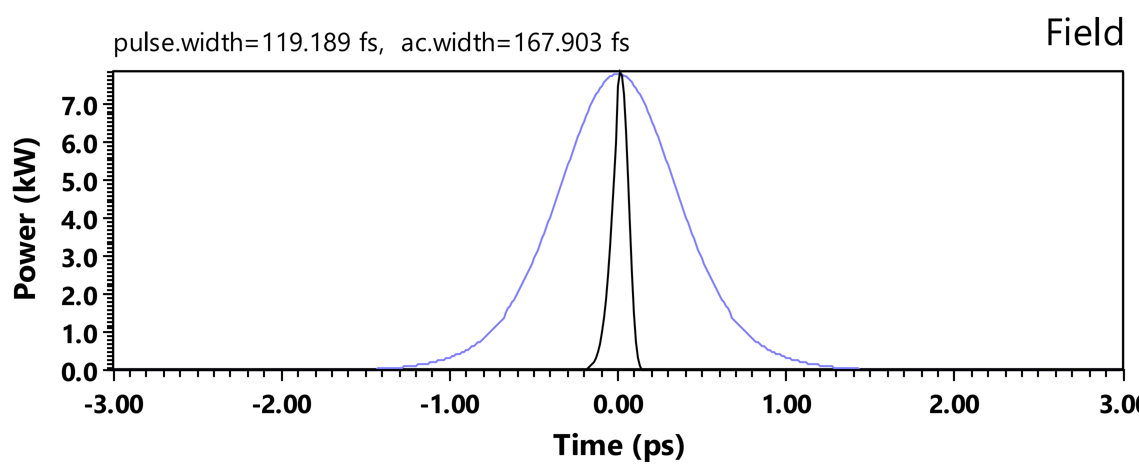
lecture 4



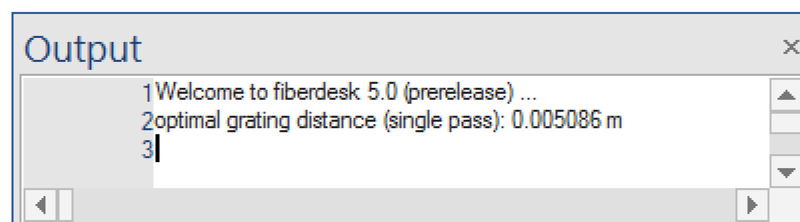
pulse compression

automatic compression minimizes autocorrelation width



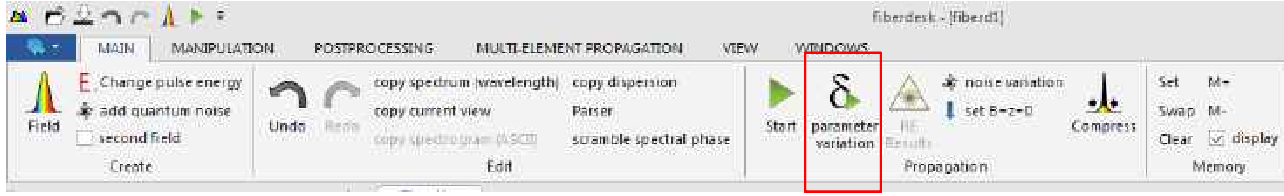


Optimized distance out via „output“ window



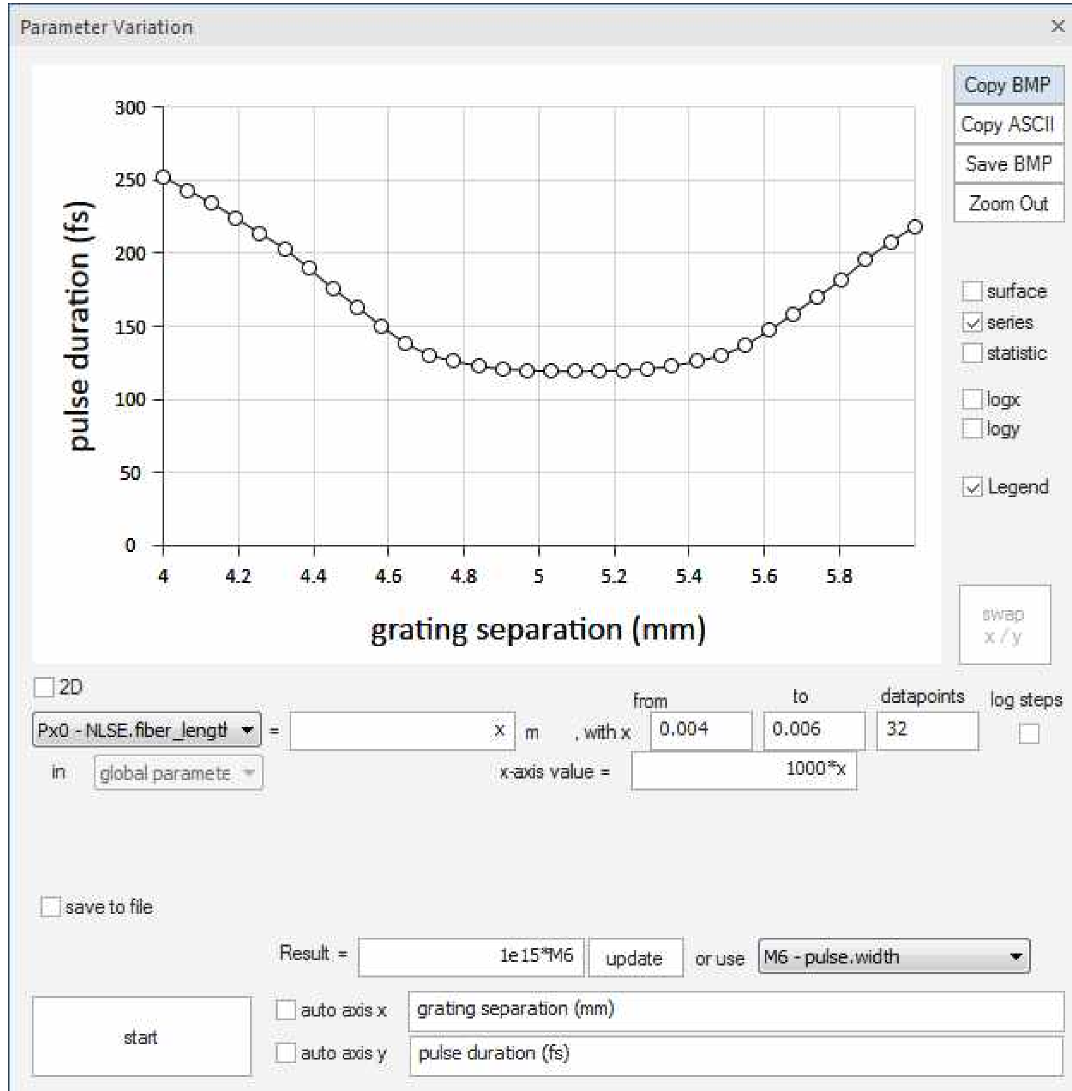
fiberdesk
nonlinear pulse propagation

lecture 4



pulse compression

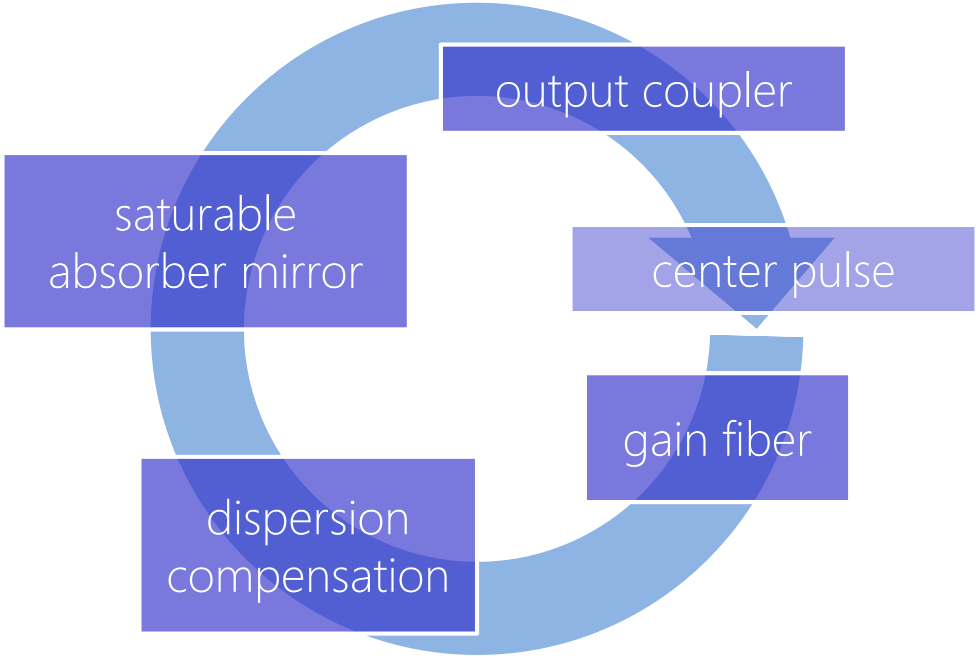
Or via parameter variation (e.g. length by setting up a dispersive element)



lecture 5

Multi-Element Propagation

lecture 5



Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

- fiber laser cavity:

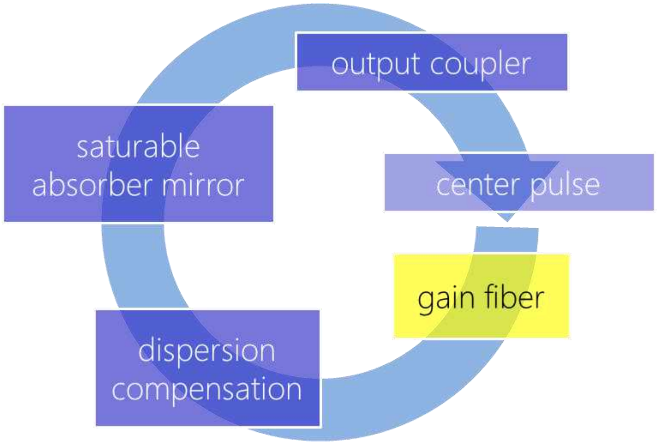
ring cavity
Fast saturable absorber modelled by reflectivity R

$$R = R_{unsat} + R_{sat} \cdot \left(1 - \frac{1}{1 + P / P_{sat}}\right)$$

- modelling of each part by the NLSE

$$iA_z + \frac{g}{2} A + i\beta_2 A_{tt} = i\gamma |A|^2 A$$

lecture 5

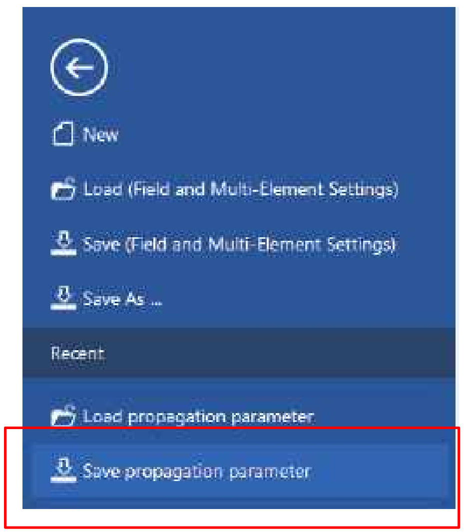


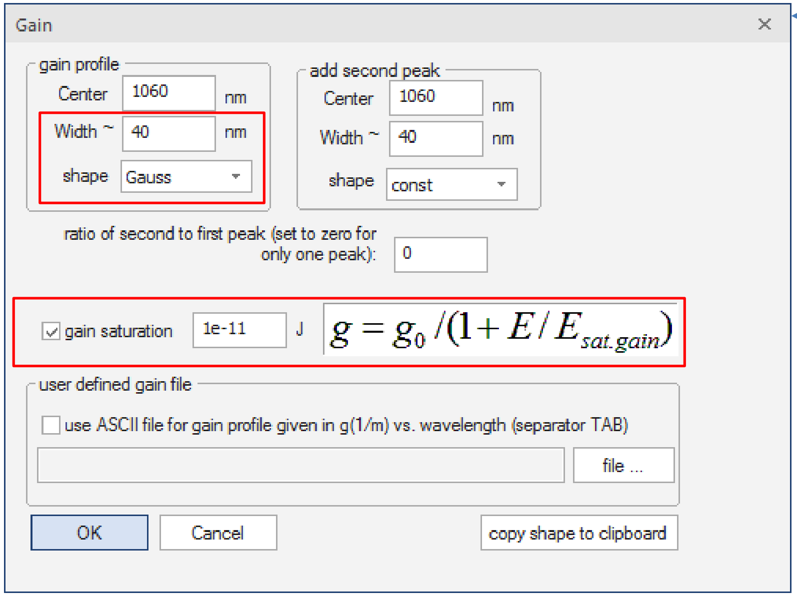
Multi-Element Propagation:

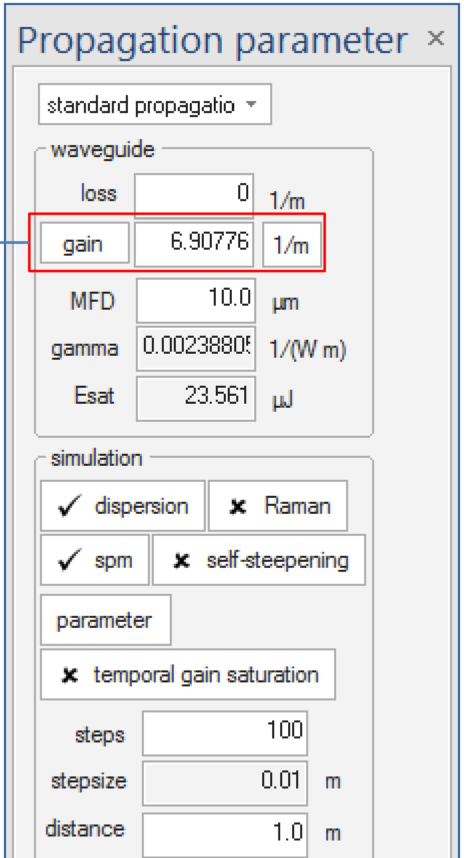
Example: Short Pulse Fiber Lasers

Set up the gain fiber as a standard propagation with saturable gain

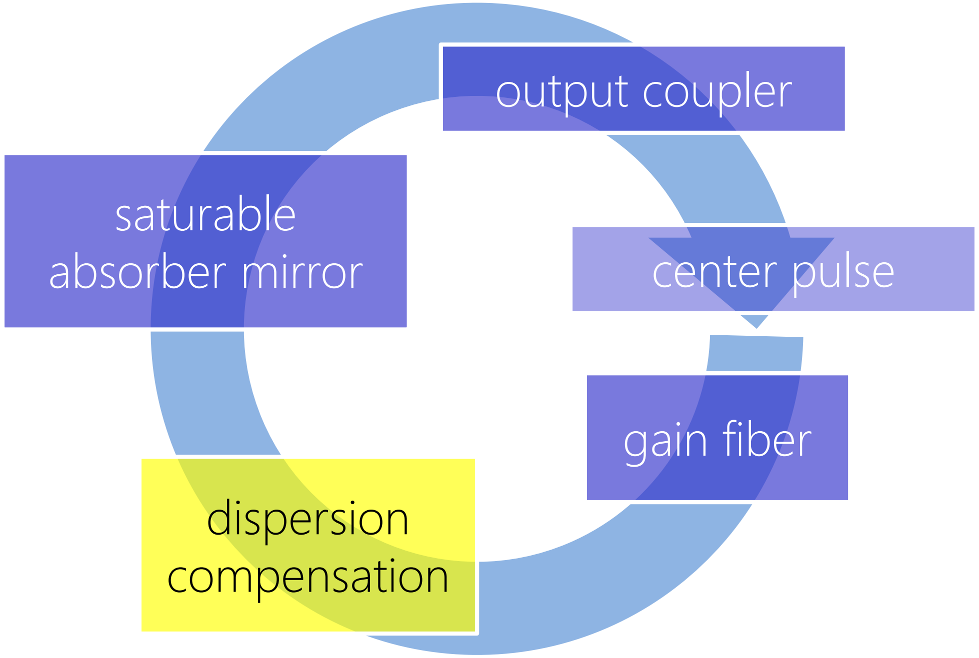
save as fiber.ppf





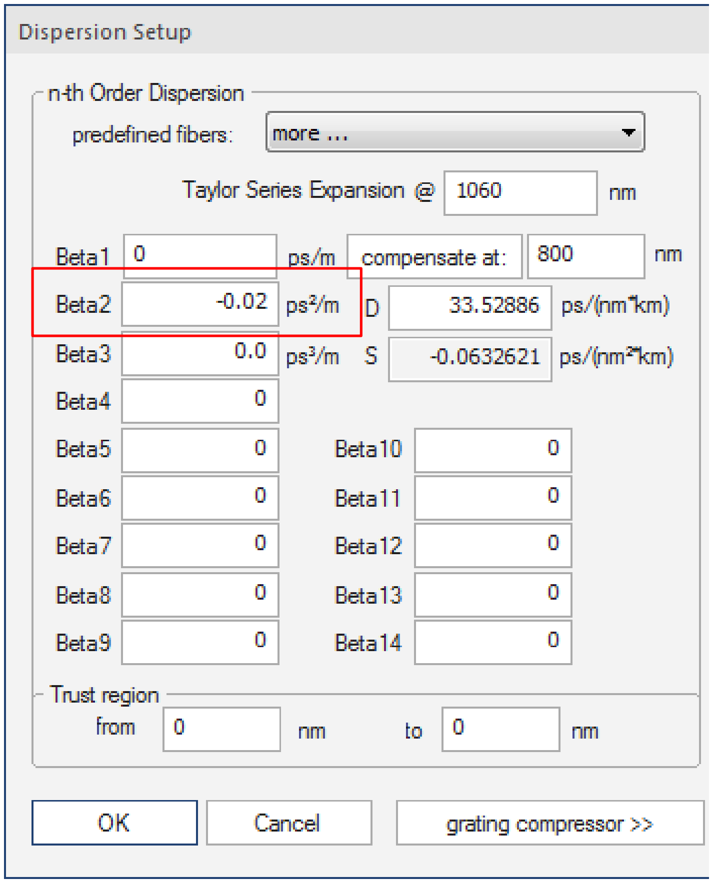


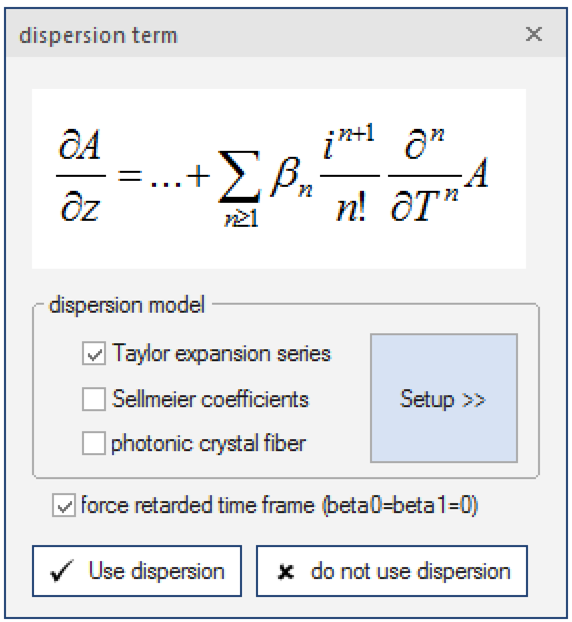
lecture 5

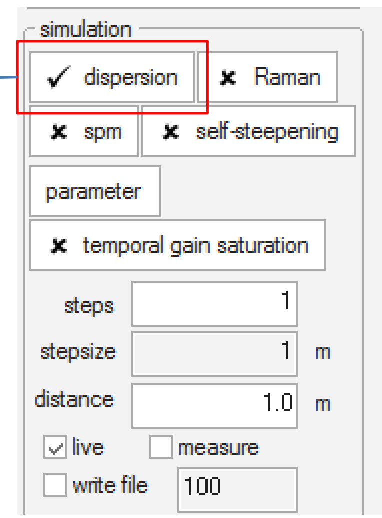


Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

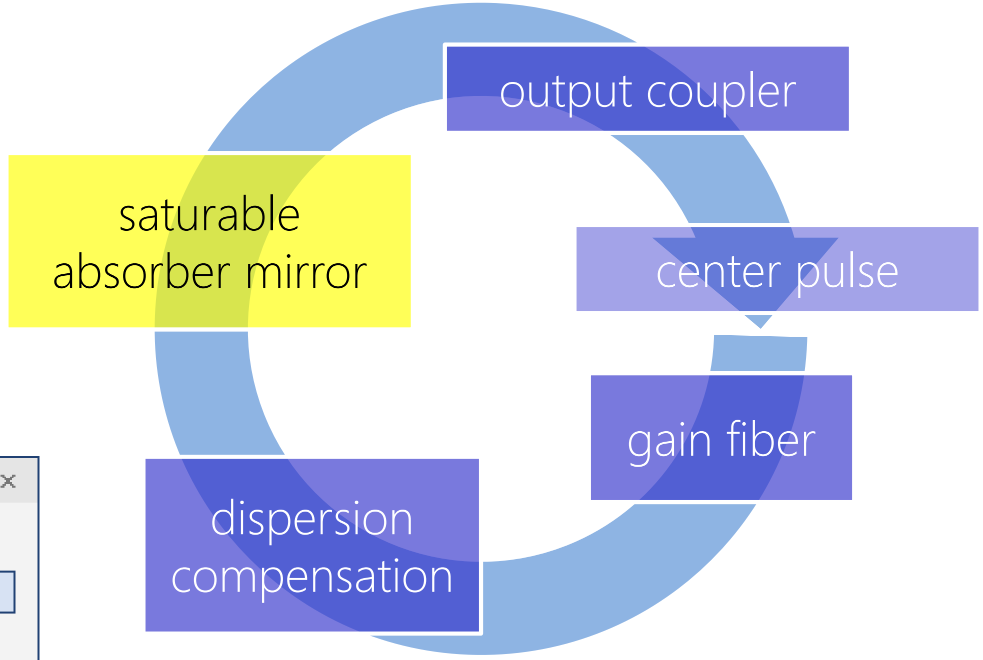






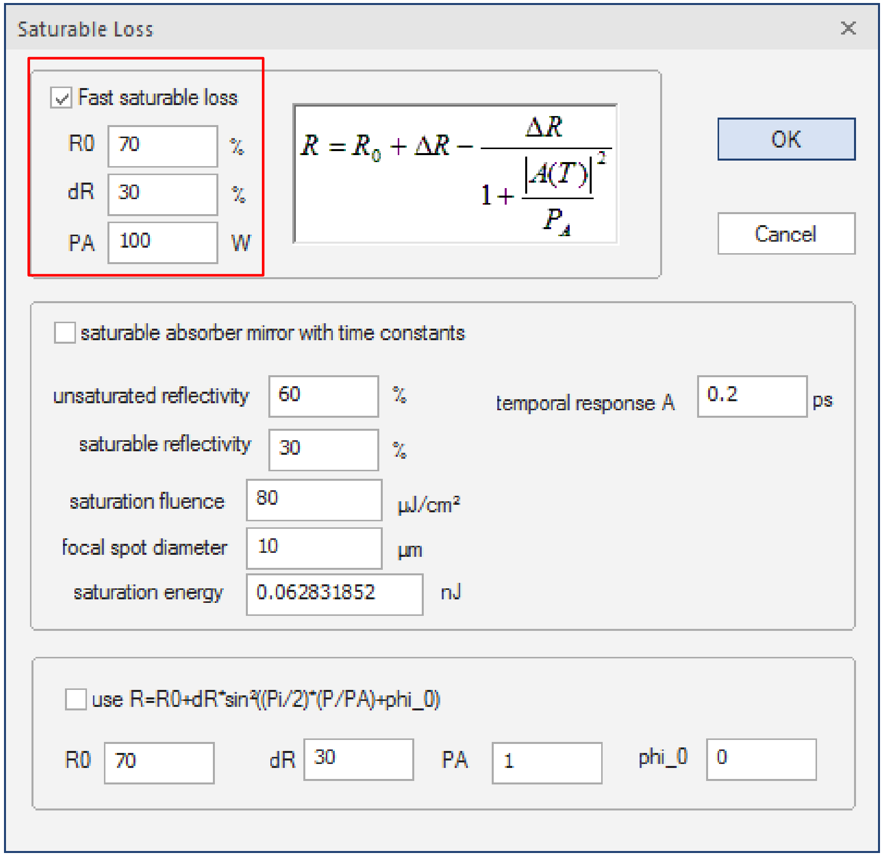
save as dc.ppf

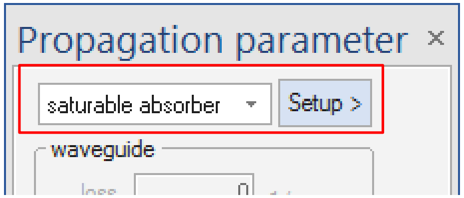
lecture 5



Multi-Element Propagation:

Example: Short Pulse Fiber Lasers





save as SA.ppf

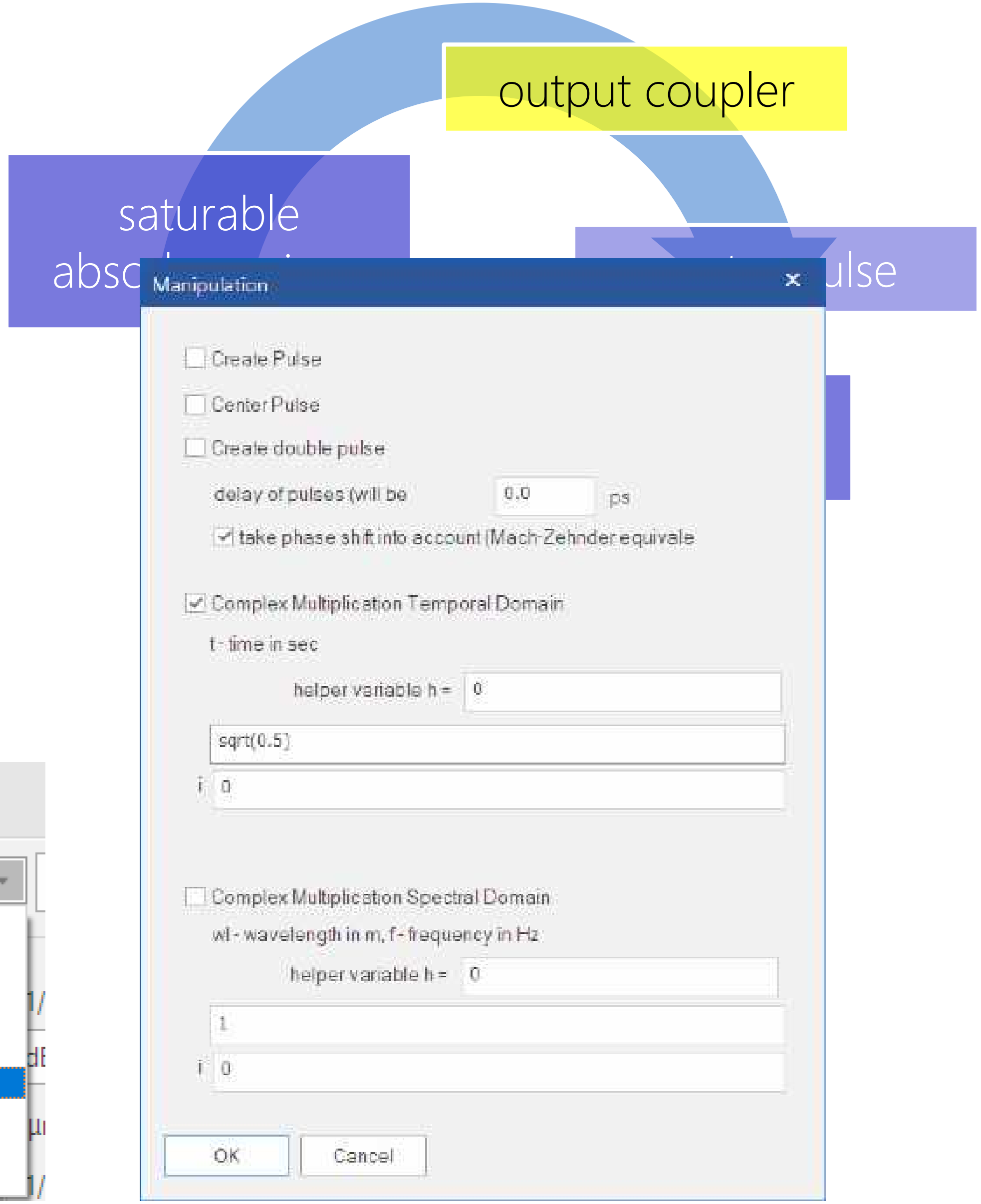
lecture 5

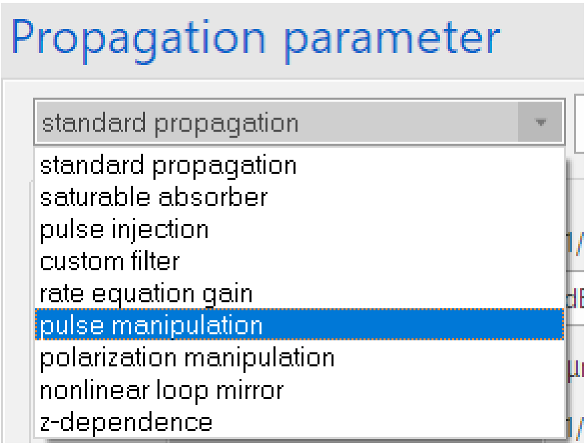
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

Outcoupling:

50% means complex multiplication with sqrt(0.5)



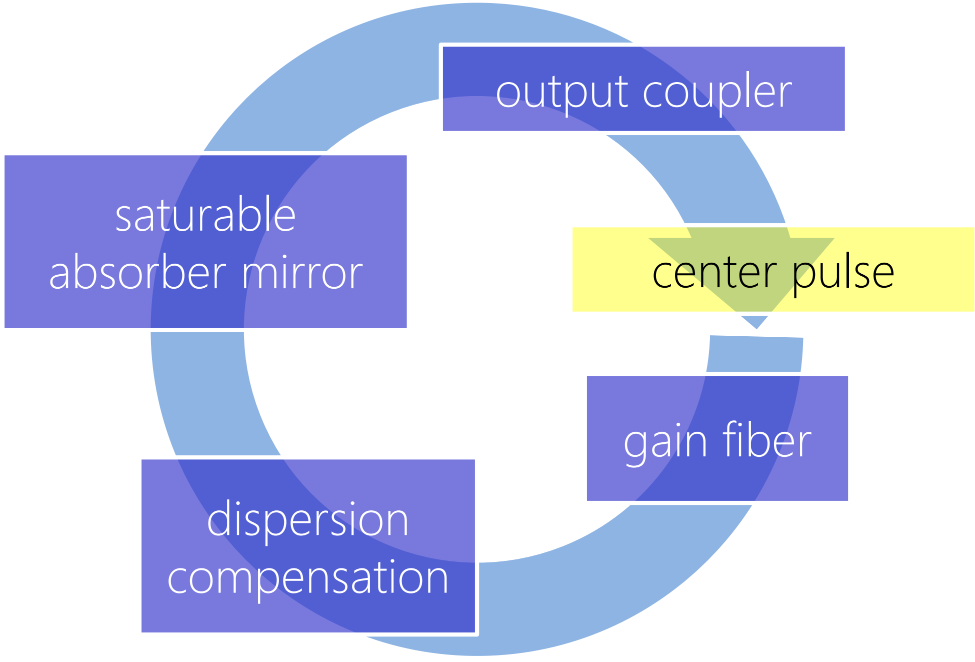


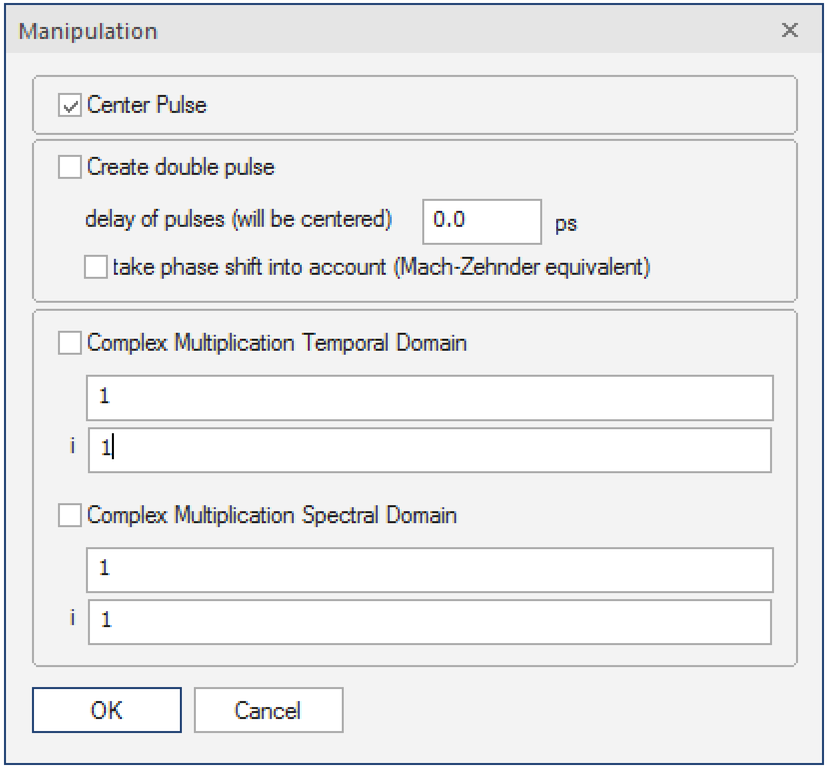
save as OC.ppf

lecture 5

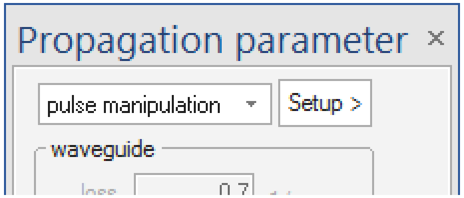
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers



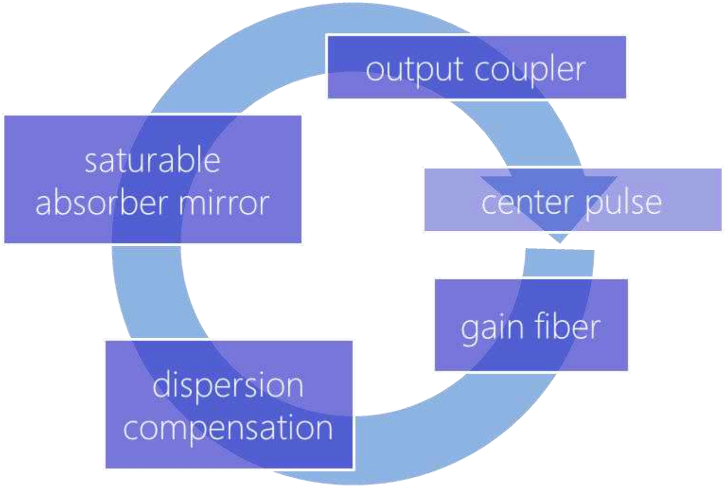


- Center pulse in the time domain, helps to converge the pulse, as change is measured in the time domain
- Can be combined with OC.ppf



save as center.ppf

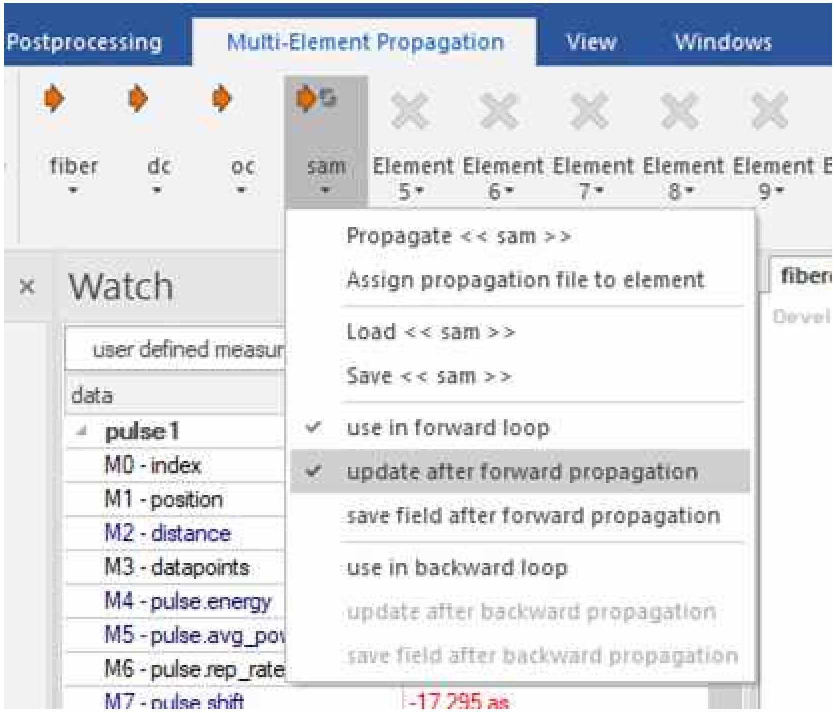
lecture 5



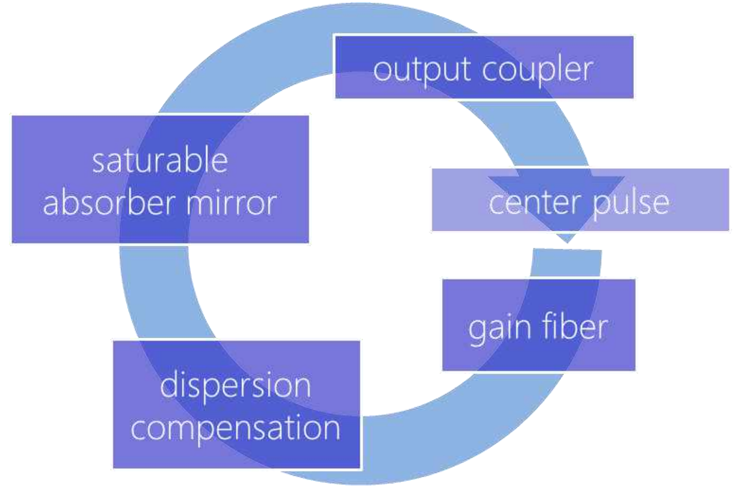
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

- assign all files to elements in the order of the cavity
- Select the last one to be updated after each loop to see convergence live
- Icons change according to selected status



lecture 5

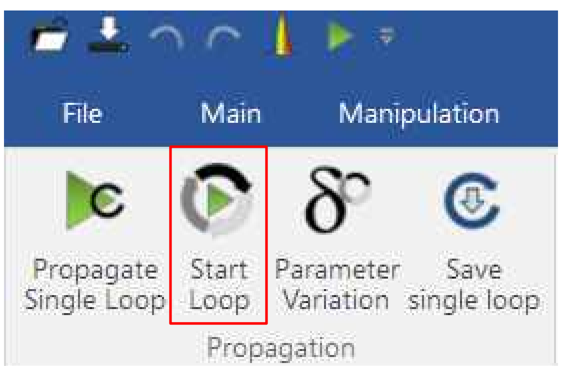


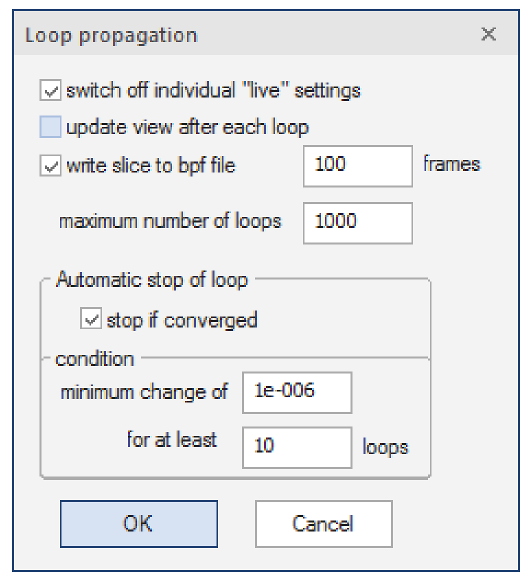
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

(1) create initial pulse, e.g. quantum noise

(2) start loop (switch on „write slice … „ for later postprocessing)



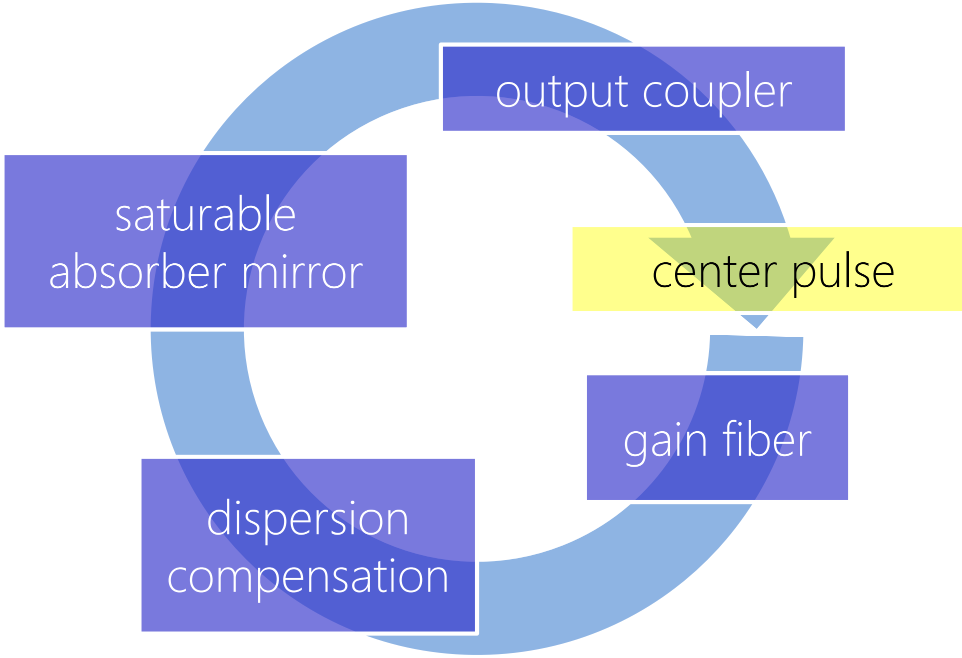


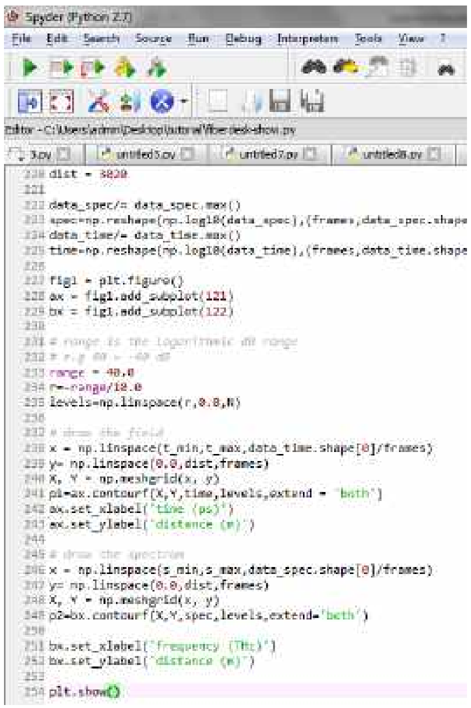
lecture 5

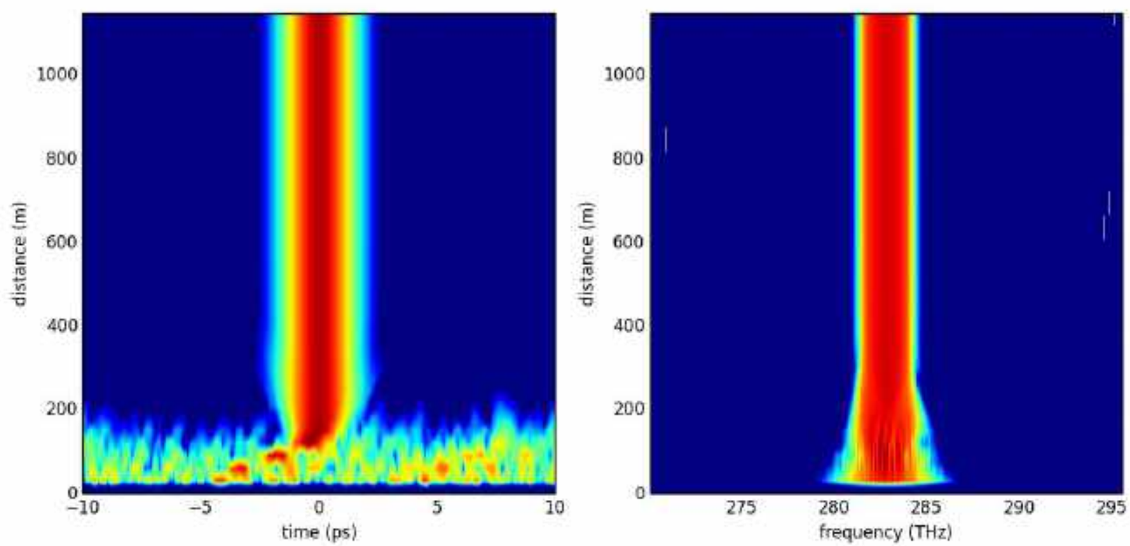
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

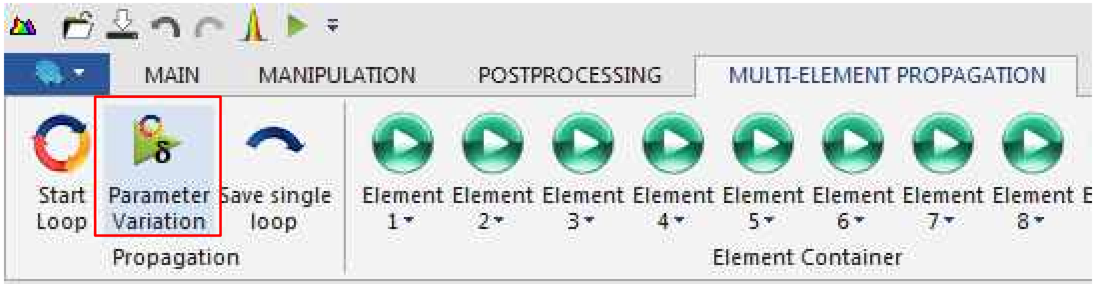
Postprocessing > Python





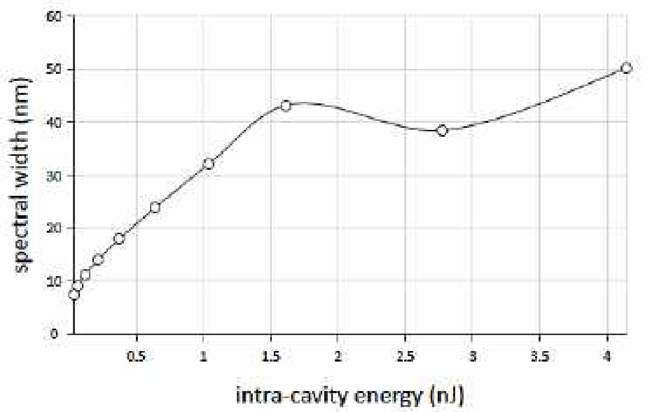


lecture 5



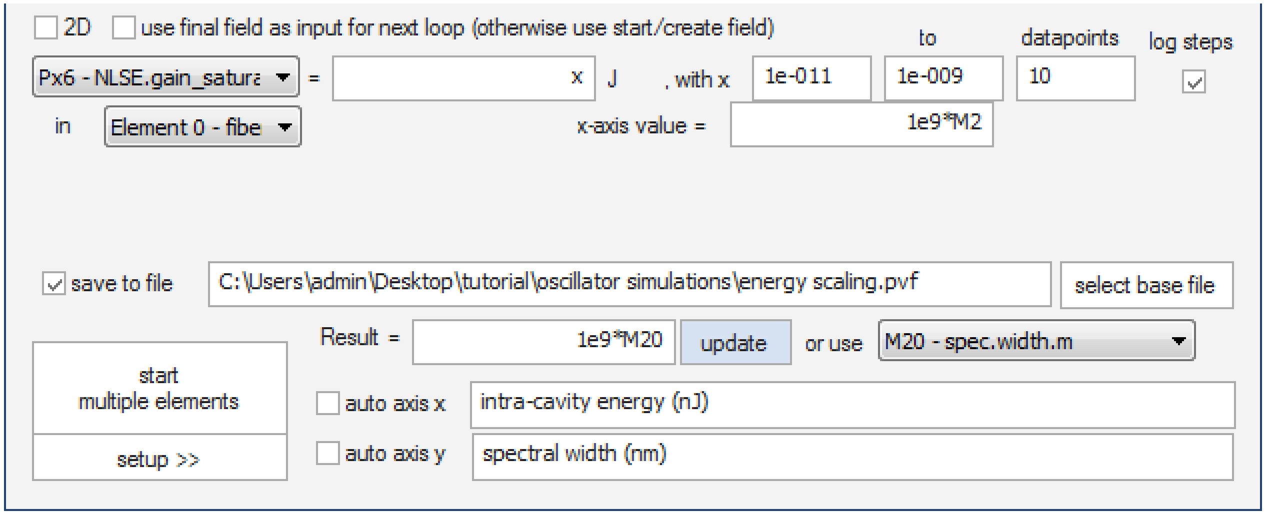
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

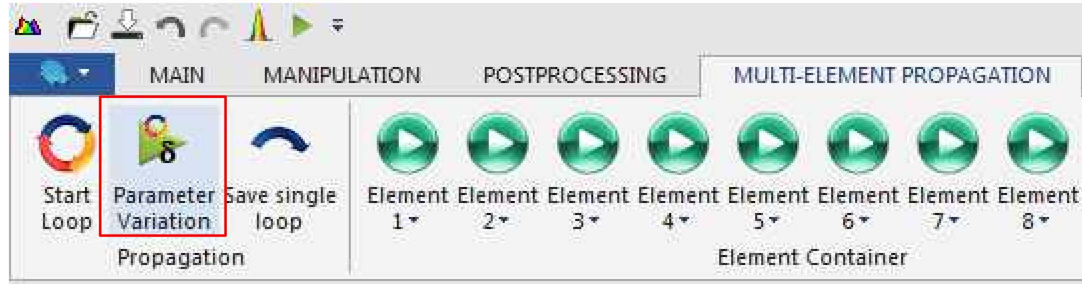


Multi-element > Parameter variation

we change the gain saturation to increase the energy (remark: intracavity energy!)



lecture 5

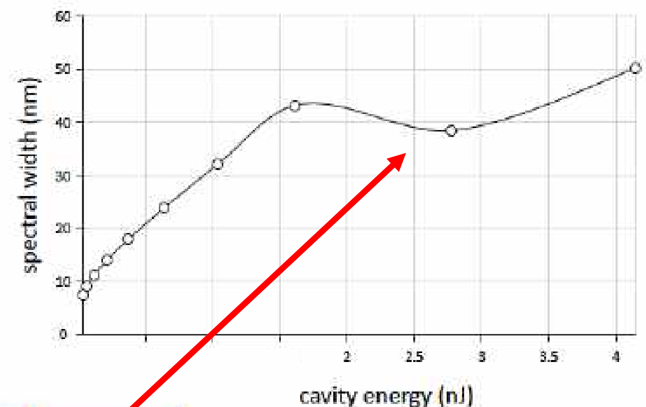


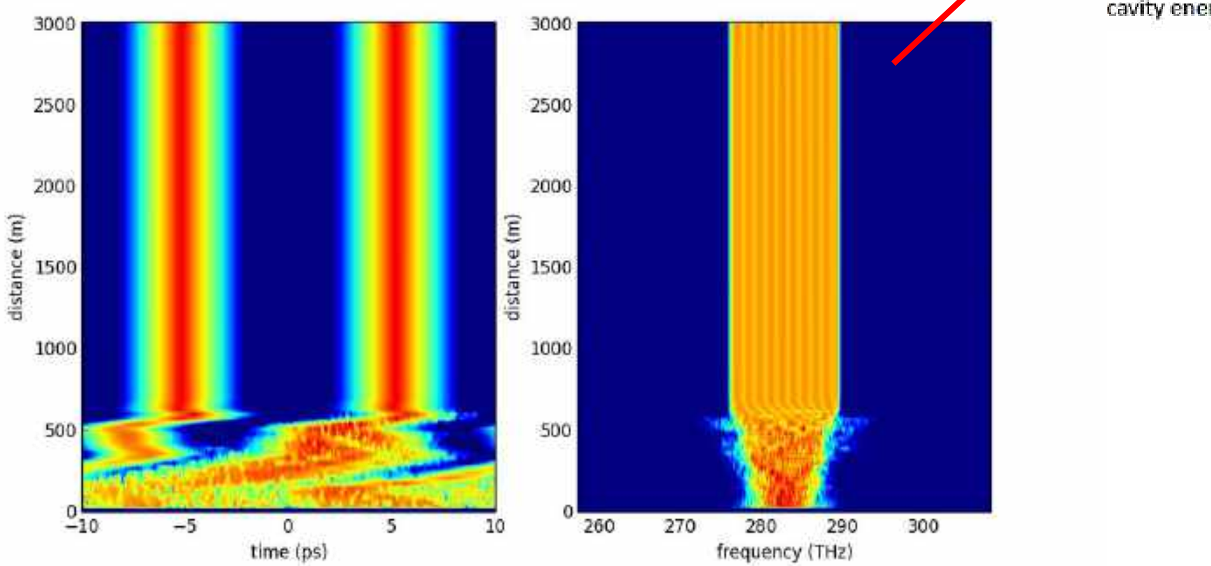
Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

Multi-element > Parameter variation

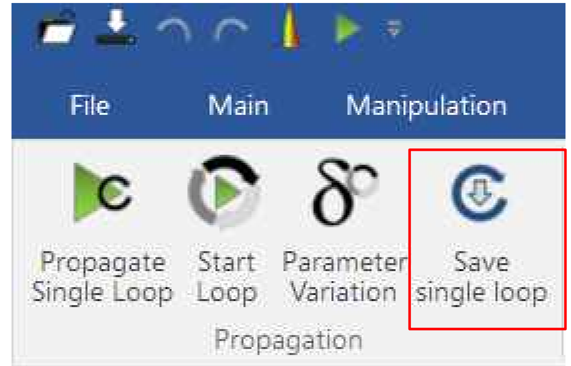
we change the gain saturation to increase the energy (remark: intracavity energy!)





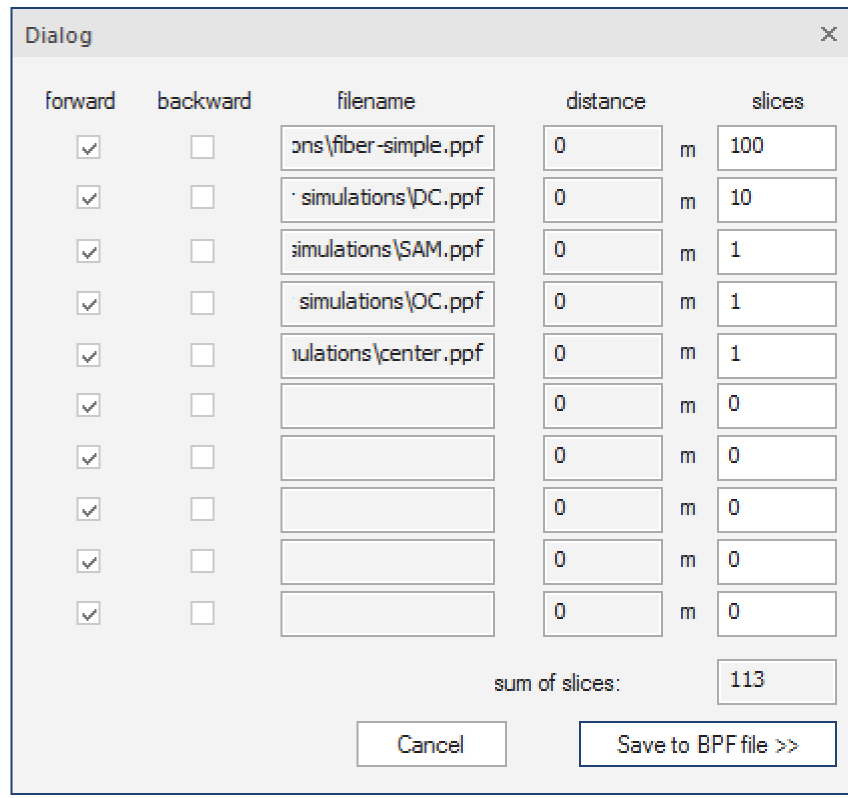
fiberdesk
nonlinear pulse propagation

lecture 5



Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

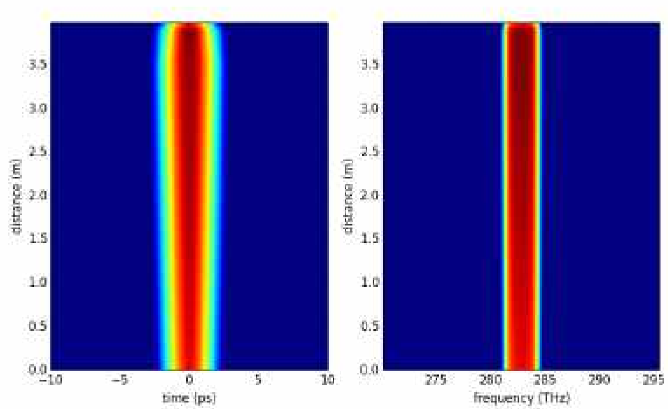


Intracavity evolution

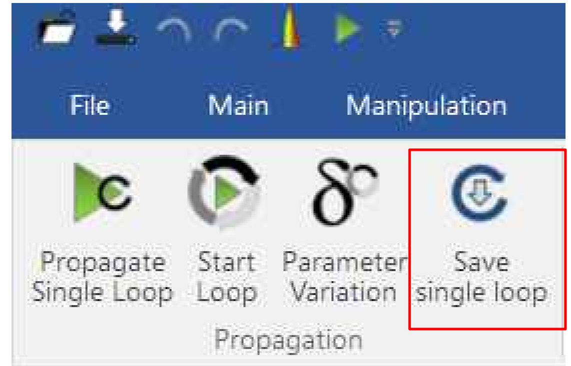
(1) select stable solution from saved file

(2) specify slices to be saved

(3) post-process



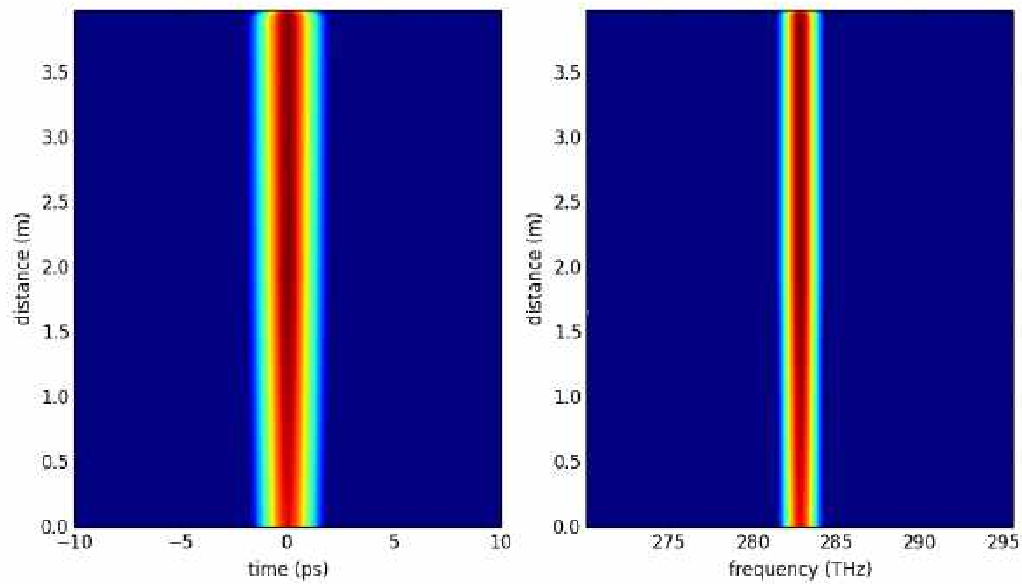
lecture 5

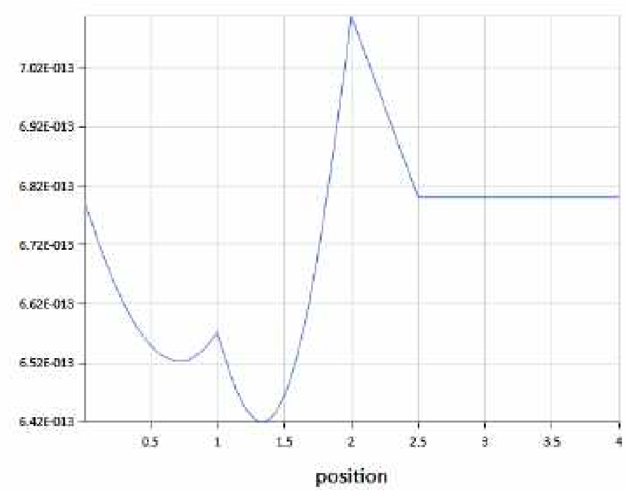


Multi-Element Propagation:

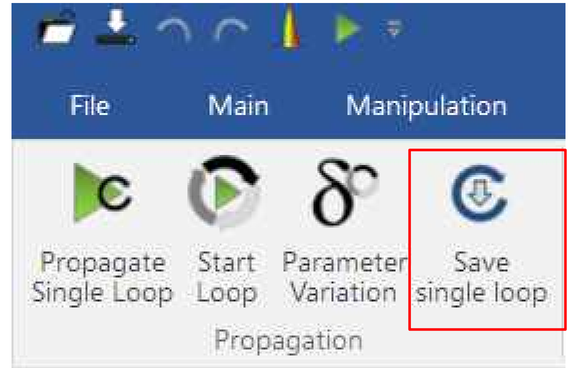
Example: Short Pulse Fiber Lasers

soliton solution: beta2@DC = -0.06 ps²





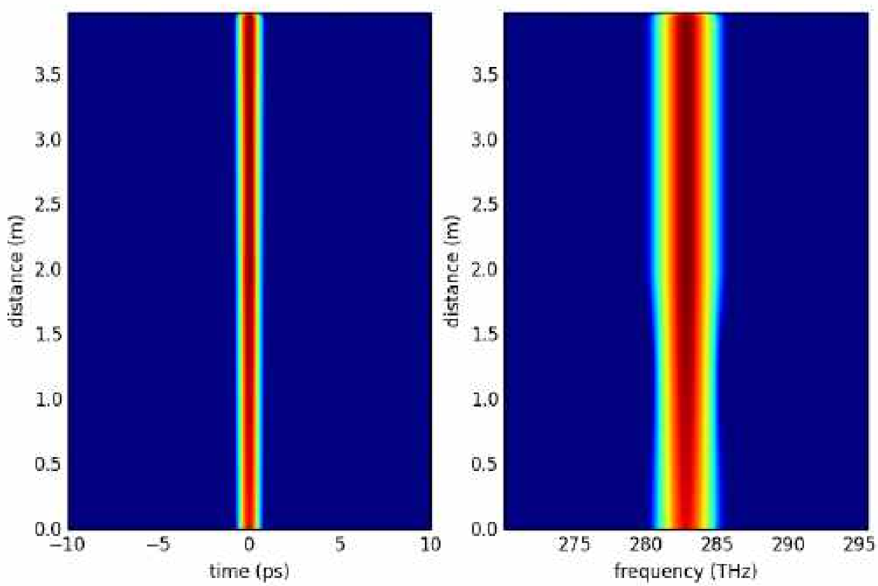
lecture 5

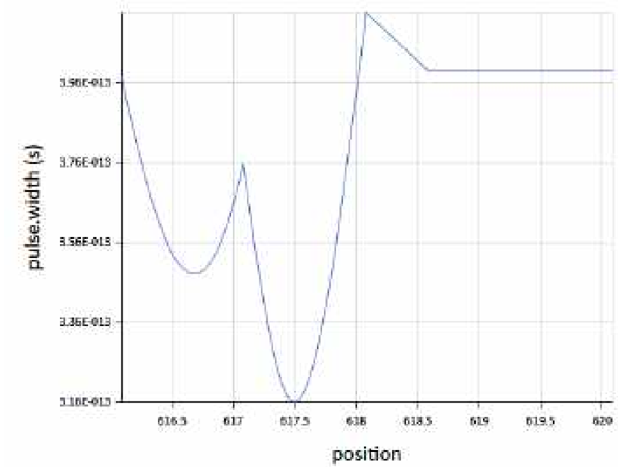


Multi-Element Propagation:

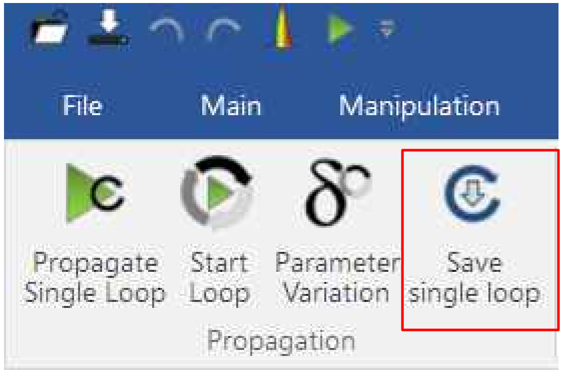
Example: Short Pulse Fiber Lasers

soliton solution: beta2@DC = -0.04 ps^2





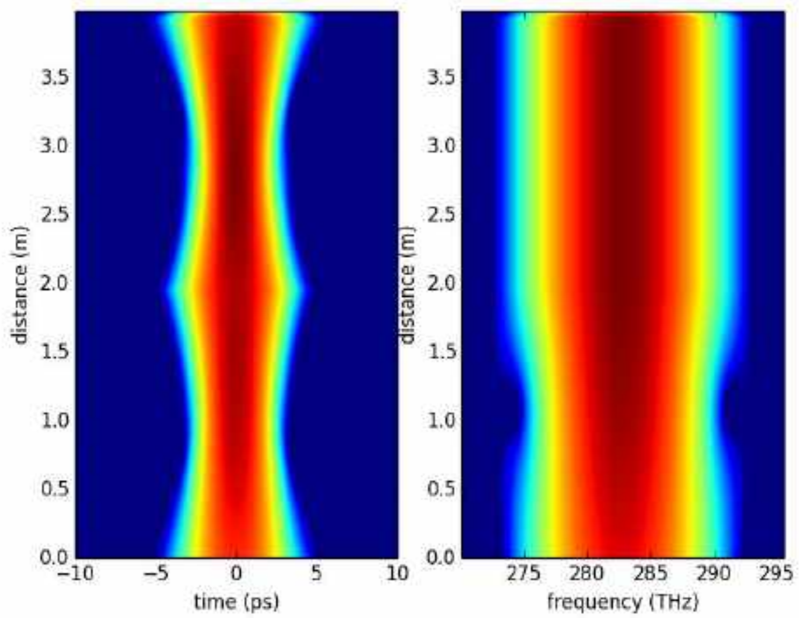
lecture 5

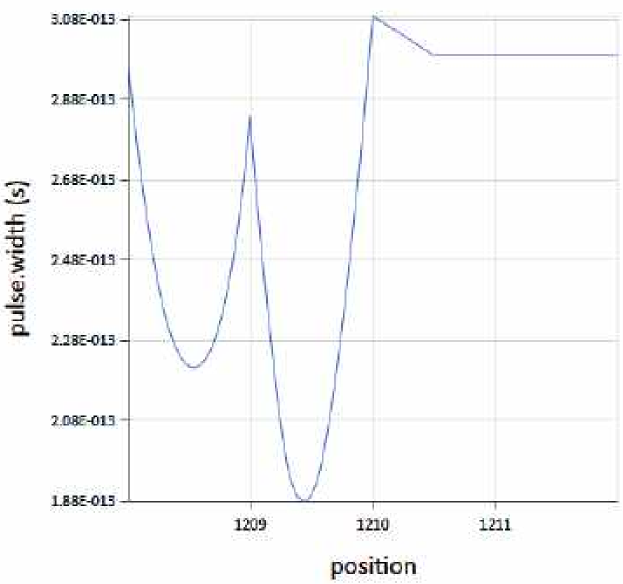


Multi-Element Propagation:

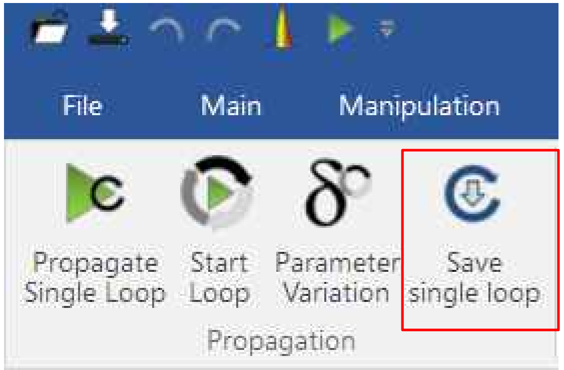
Example: Short Pulse Fiber Lasers

toward stretched pulse: beta2@DC = -0.03 ps^2





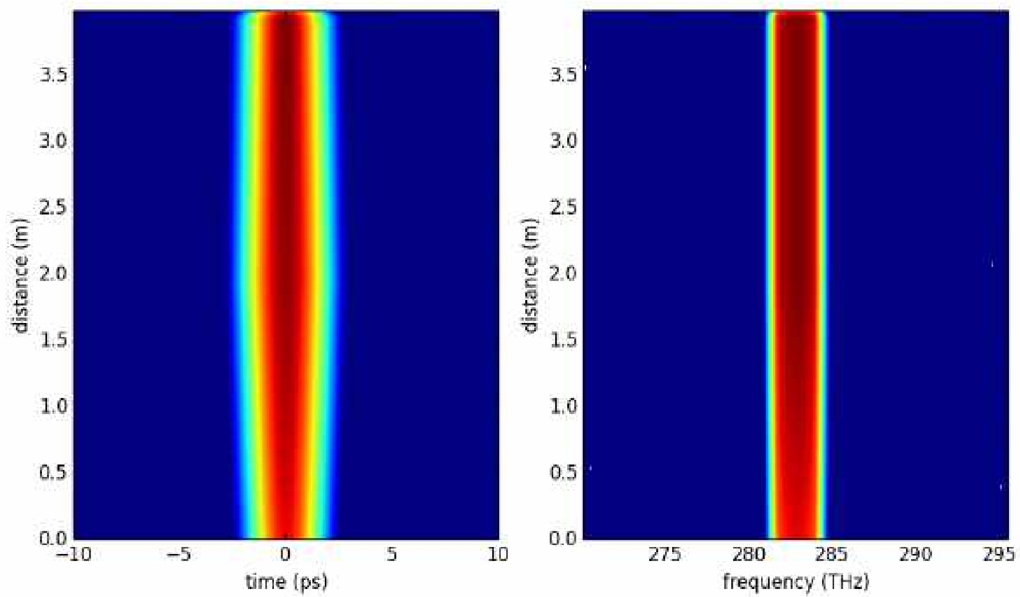
lecture 5

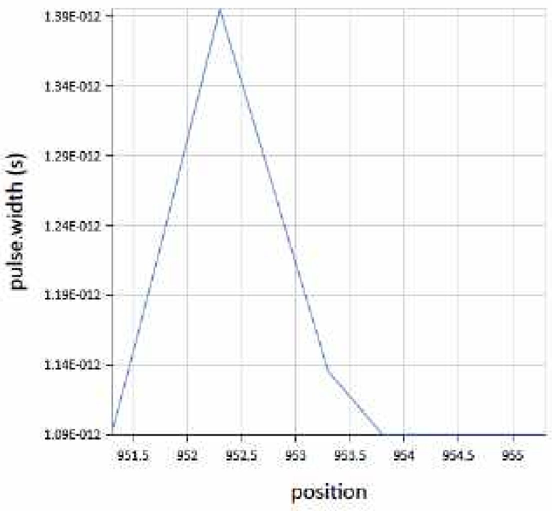


Multi-Element Propagation:

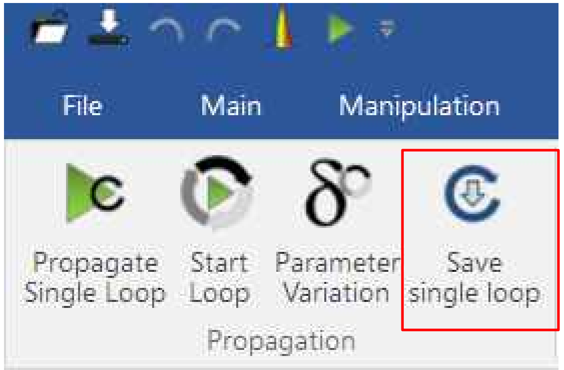
Example: Short Pulse Fiber Lasers

similariton: beta2@DC = -0.02 ps^2





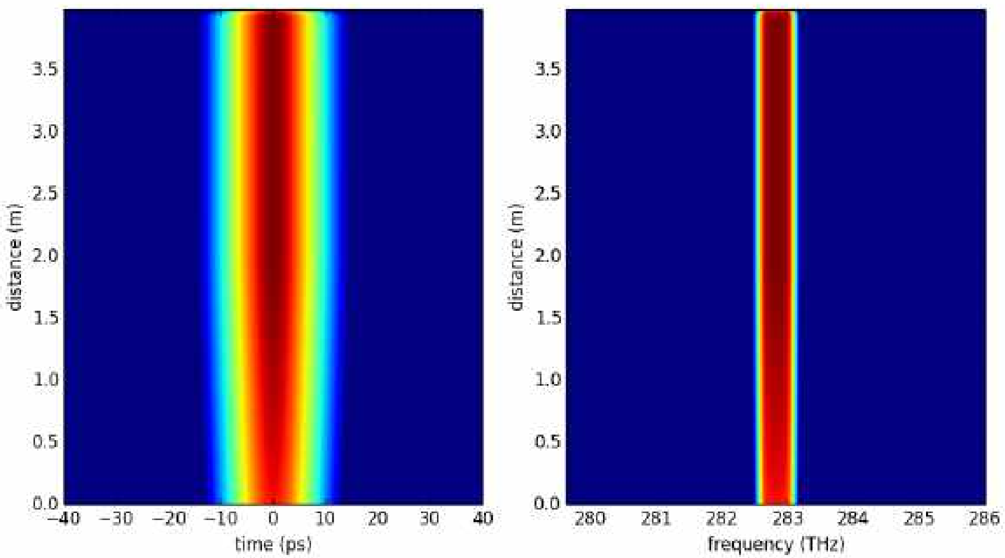
lecture 5

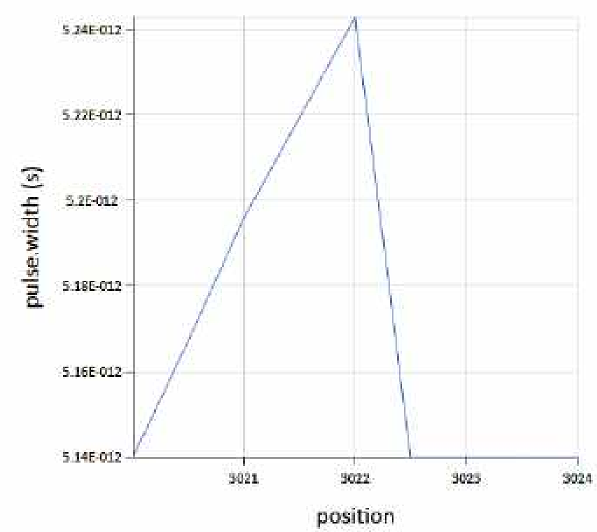


Multi-Element Propagation:

Example: Short Pulse Fiber Lasers

chirped pulse oscillator: beta2@DC = +0.02 ps^2





lecture 6

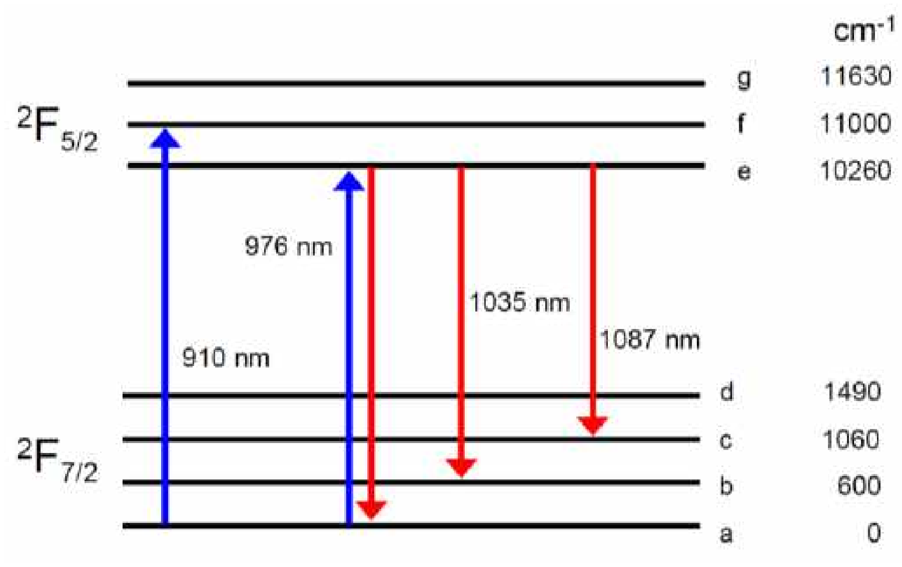
Rate-equation gain

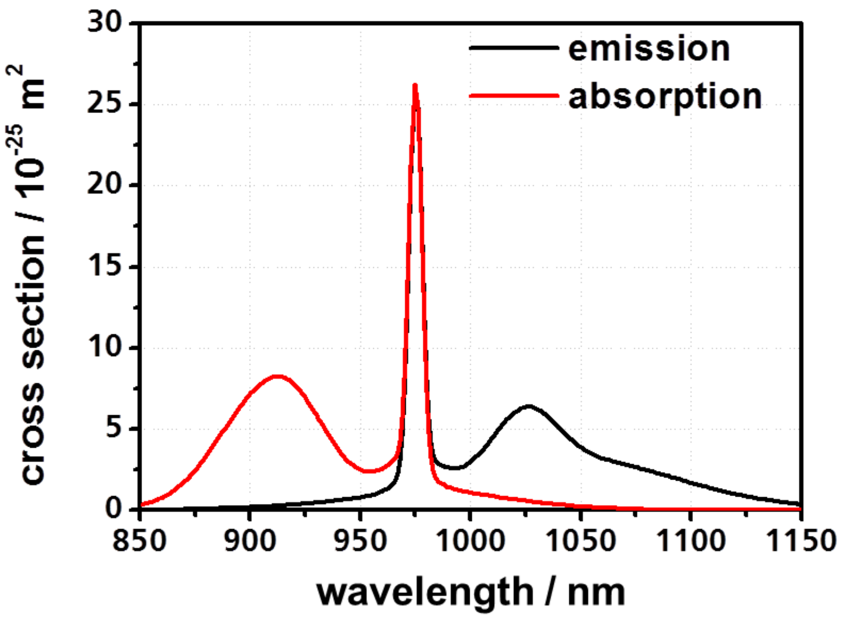
(1) Simple cw oscillators
(2) Nonlinear fiber amplifiers (in preparation)

lecture 6

Rate-equation gain

Solution of stationary rate-equation (effectivly two level system) to describe pump- and signal powers as well as inversion in lasers and amplifiers.





lecture 6

Rate-equation gain

Solution of stationary rate-equation (effectivly two level system) to describe pump- and signal powers as well as inversion in lasers and amplifiers.

$$\frac{dP_{P/S}^{\pm}}{dz} = \pm\left(\sigma_{P/S}^{em} n_2 \mp \sigma_{P/S}^{abs} n_1 + \alpha_{P/S}\right)\cdot \Gamma_{P/S} \cdot P_{P/S}^{\pm} \overbrace{\mp \sigma_{P/S}^{em} n_2 \cdot 2 \cdot h\upsilon_{P/S} \cdot \Delta\upsilon}^{ASE}$$

$$n_2 = \frac{\displaystyle\sum_{i=P,S} \frac{\sigma_i^{abs} \cdot n_0}{h\upsilon_i} \Gamma_i P_i}{\displaystyle\sum_{i=P,S} \frac{\left(\sigma_i^{abs} + \sigma_i^{em}\right)\cdot n_0}{h\upsilon_i} \Gamma_i P_i + \frac{1}{\tau}}$$

$n_0 = n_1 + n_2$ is the sum of upper and lower population density

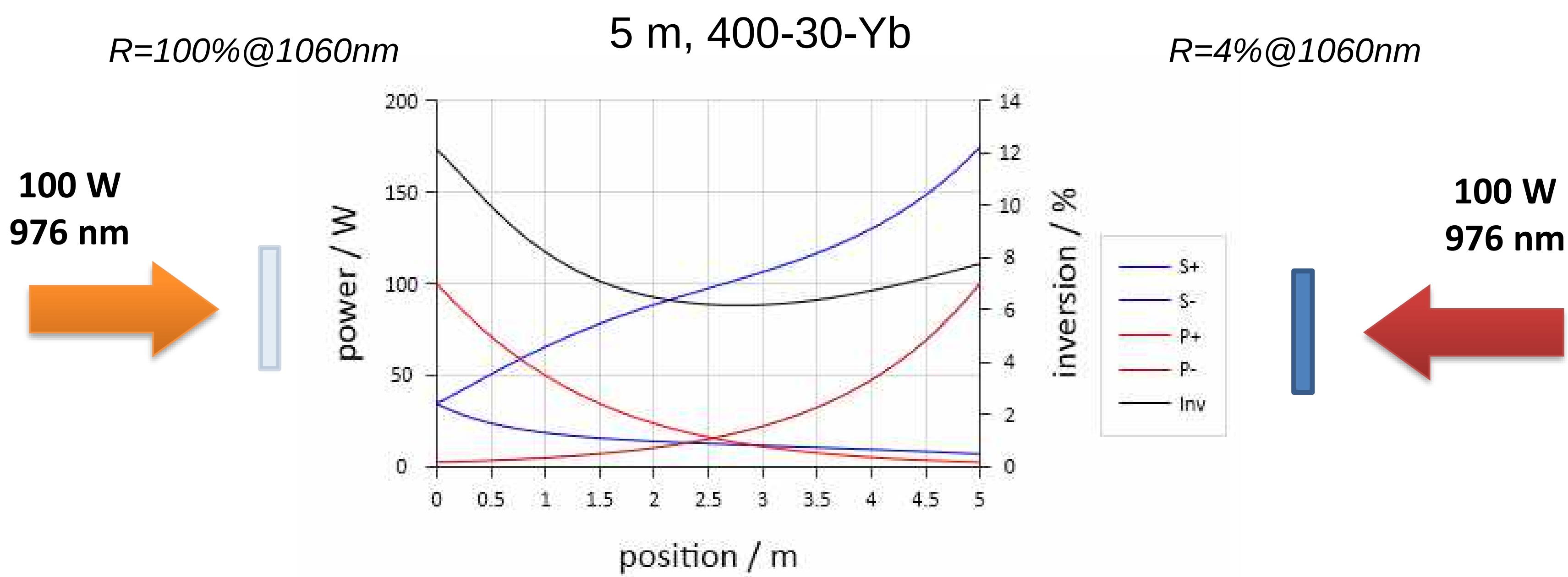
$\alpha_{P/S}$ is an additional loss (background loss)

τ as the upper state lifetime

assumed that the pump absorption can be described by a simple overlap factor Γ_p, which is the ratio of doped core area to pump core area.

lecture 6

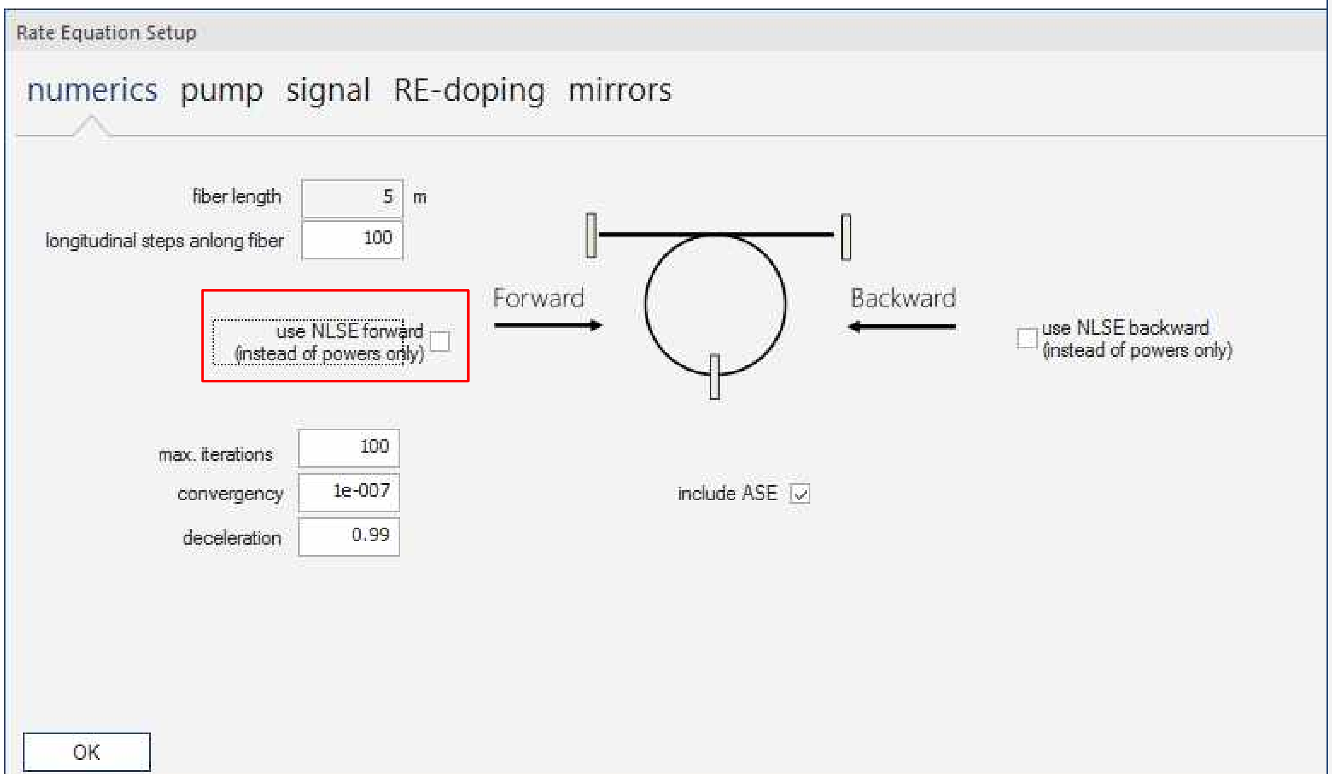
Simple cw fiber laser – pumped from both sides

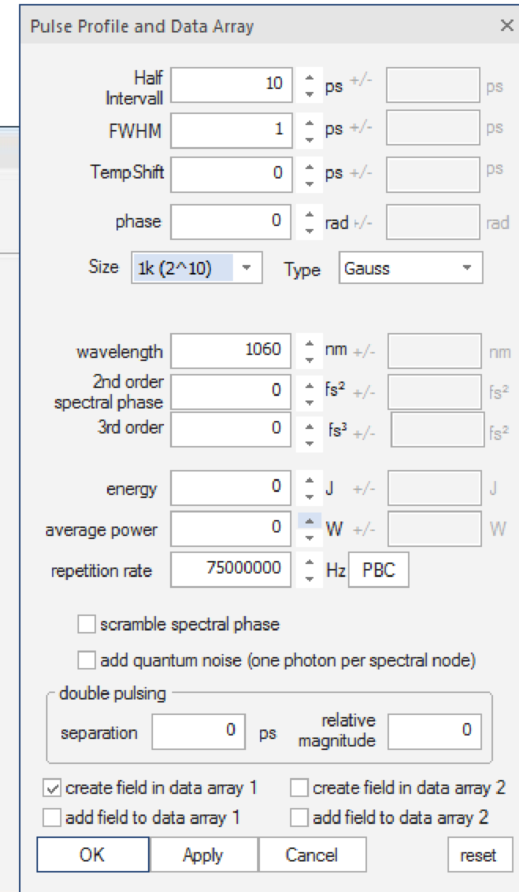


lecture 6

Simple cw fiber laser – pumped from both sides

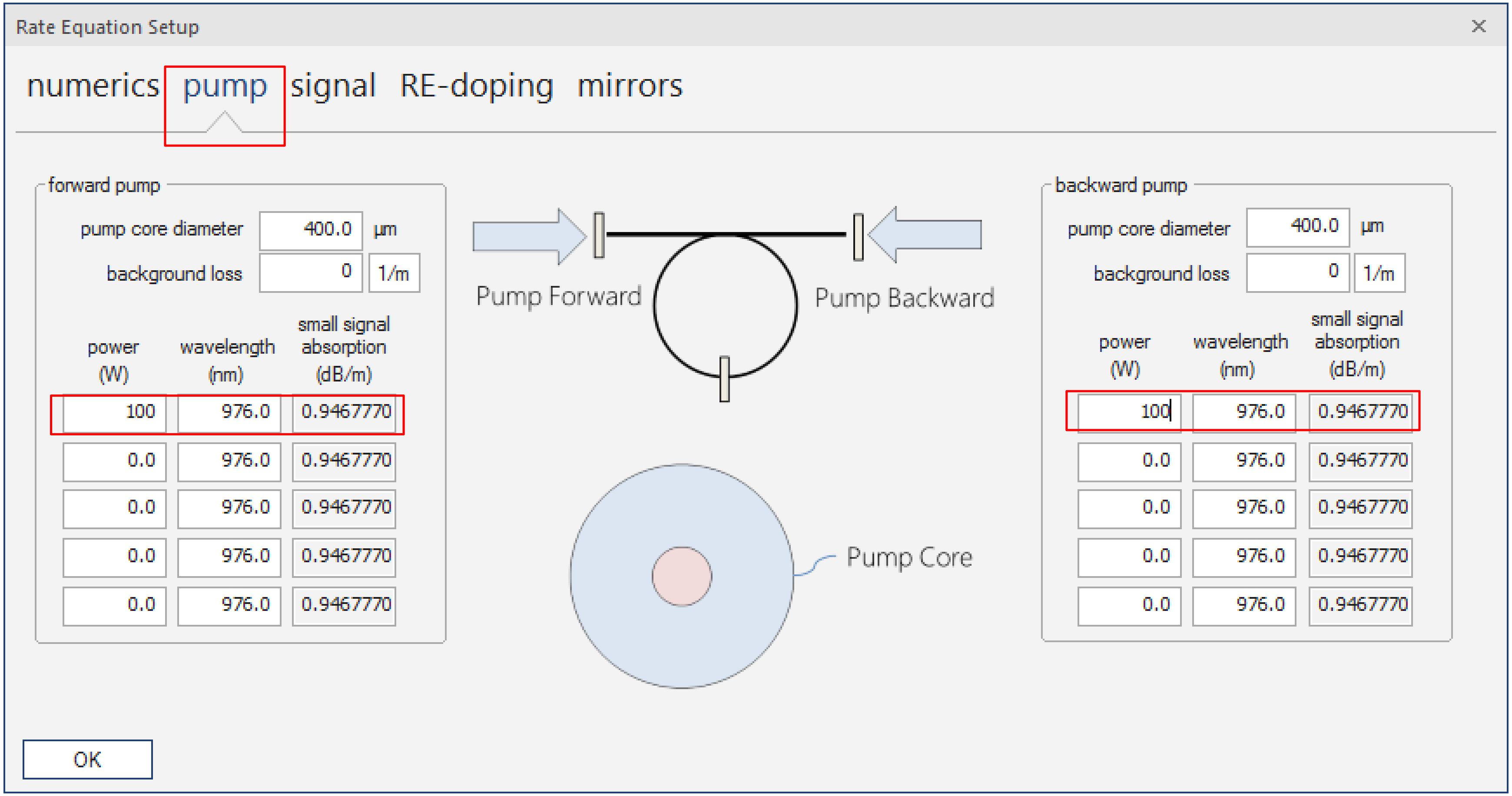
empty field and numerics first





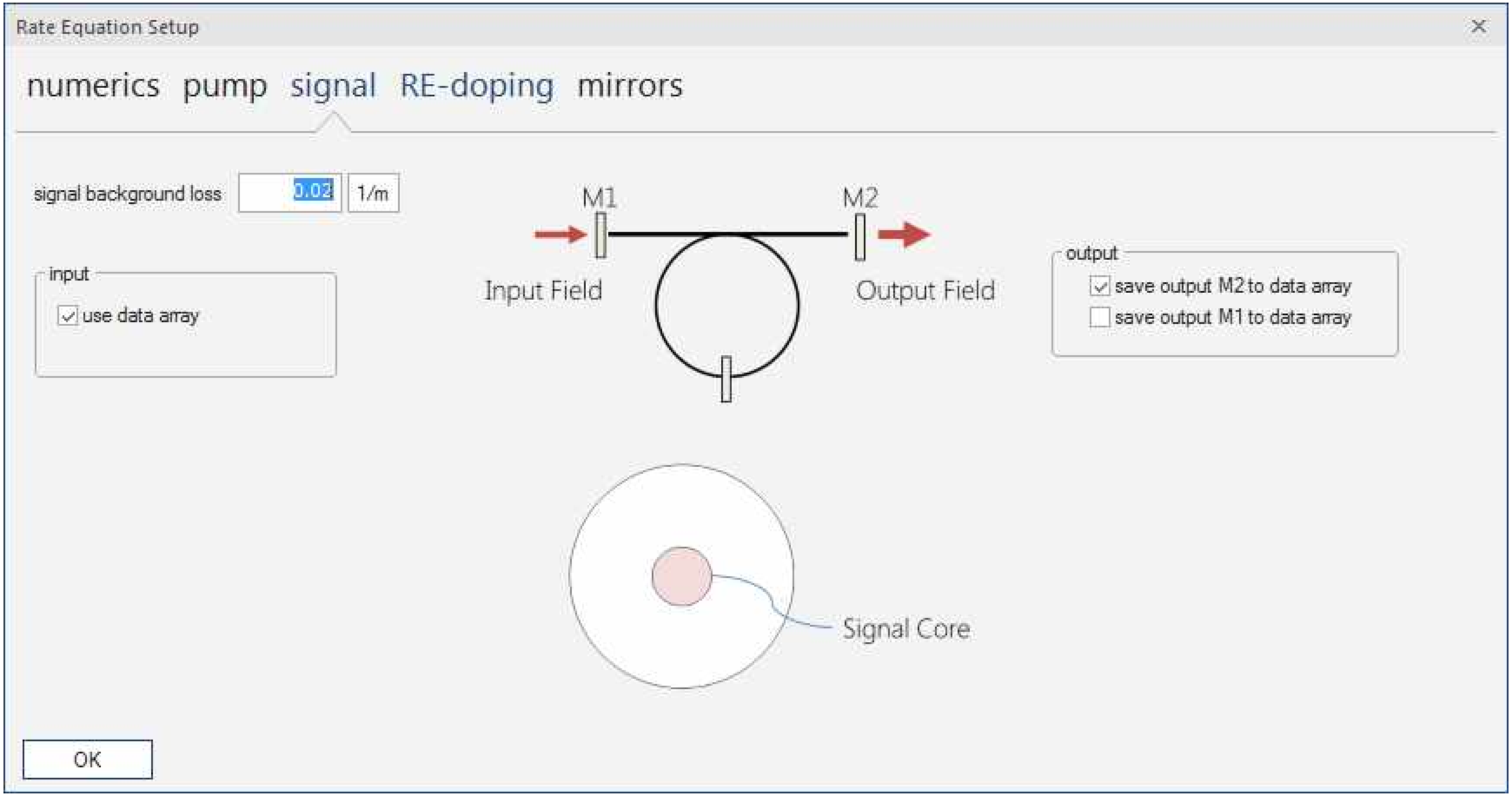
lecture 6

Simple cw fiber laser – pumped from both sides



lecture 6

Simple cw fiber laser – pumped from both sides



Simple cw fiber laser – pumped from both sides

Rate Equation Setup

numerics pump signal RE-doping mirrors

mass concentra

host material dens

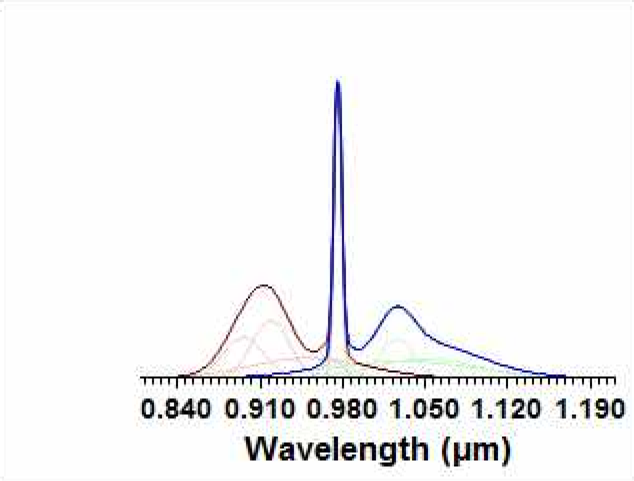
density 3.5

atomic mass ions

OK

Emission Absorption Cross Section

Emission cross section (1e-27 m²)	Emission Center (nm)	Emission Width (nm)	Absorption cross section (1e-27 m²)	Absorption Center (nm)	Absorption Width (nm)
2325	975	4	180	950	70
160	978	12	360	895	24
340	1025	20	510	918	22
175	1050	60	160	971	12
150	1030	90	2325	975	4
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

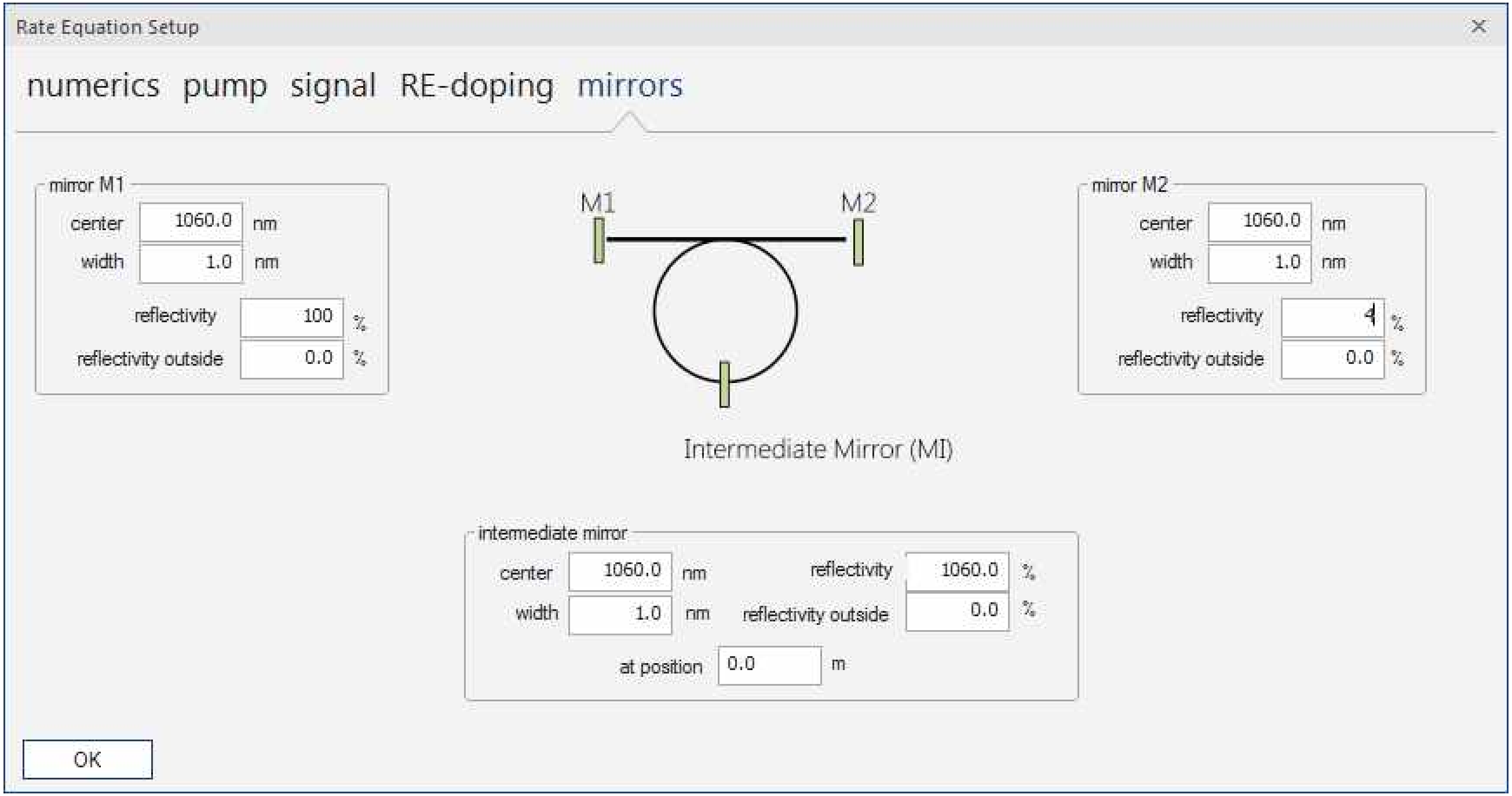


Load | Save | Copy To Clipboard (ASCII)

select cross sections ... | OK | Cancel

lecture 6

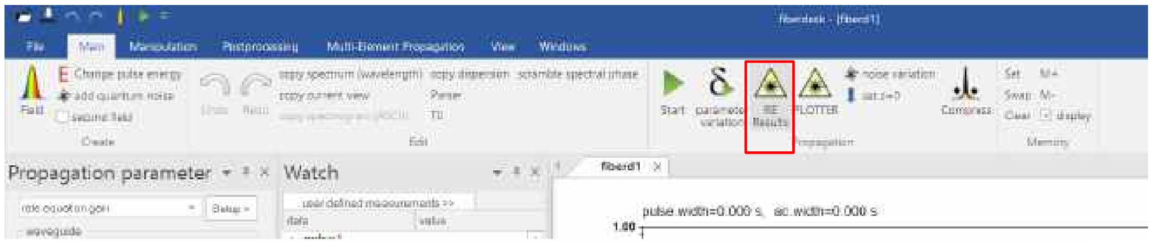
Simple cw fiber laser – pumped from both sides

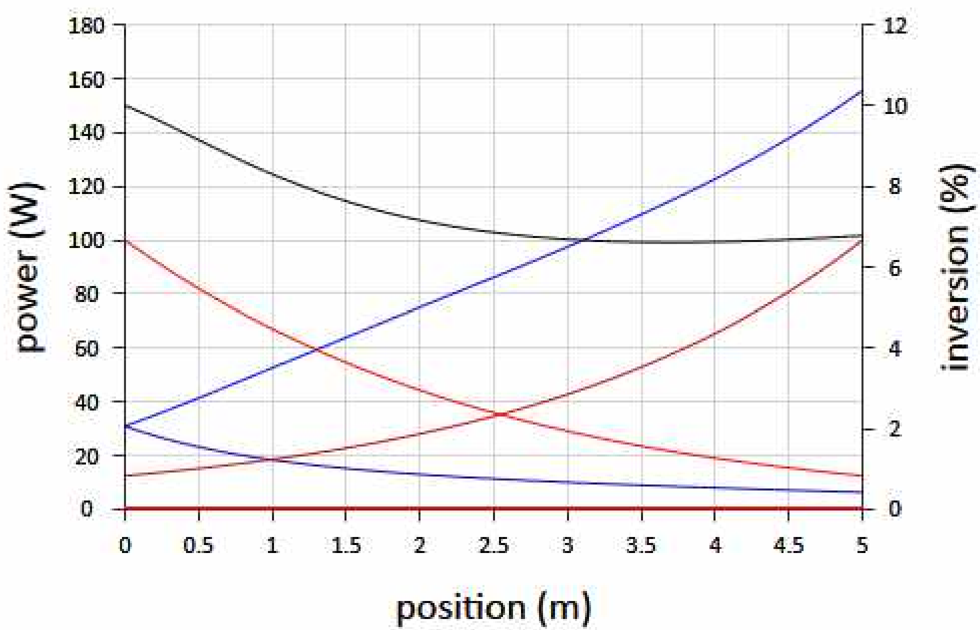


lecture 6

Simple cw fiber laser – pumped from both sides

Results:





lecture 7

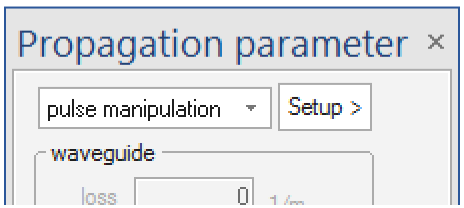
Pulse manipulation

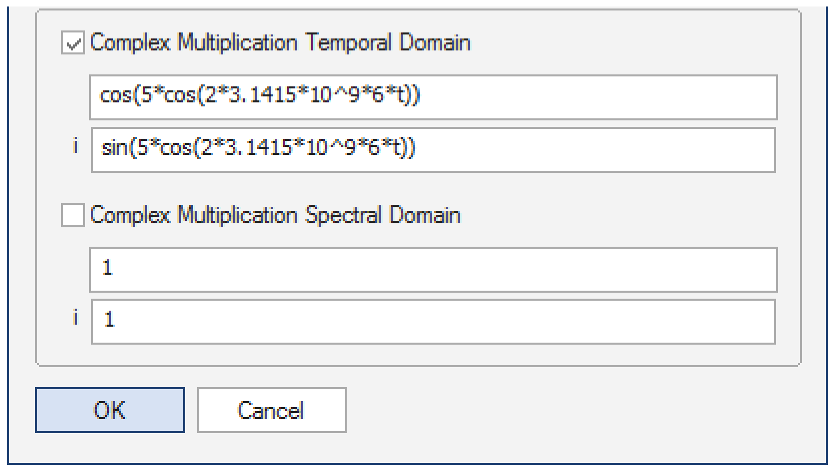
(1) Phase modulation

lecture 7

Pulse manipulation

(1) Phase modulation





lecture 8

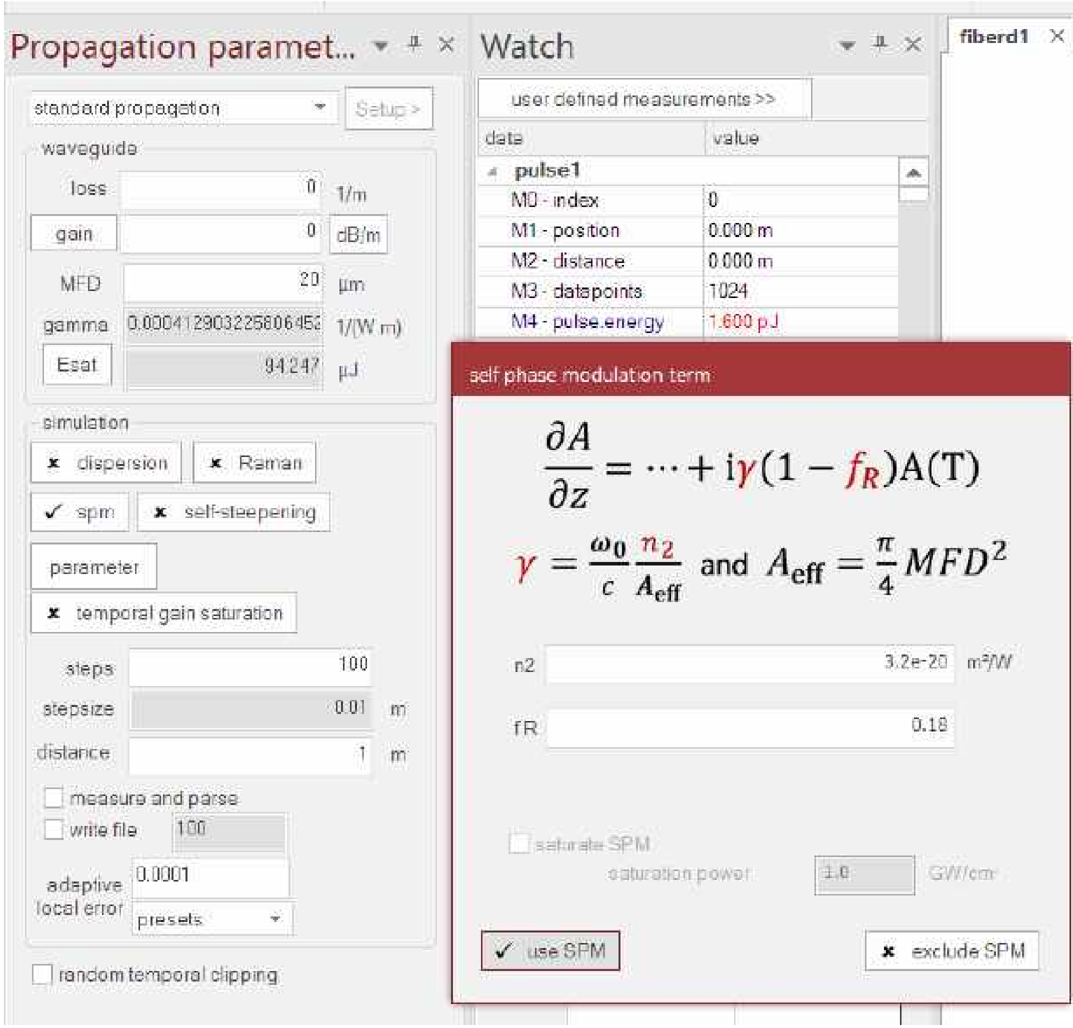
Nonlinear Optical Loop Mirror

lecture 8

Nonlinear Optical Loop Mirror

The loop shall be a single nonlinear element without dispersion.

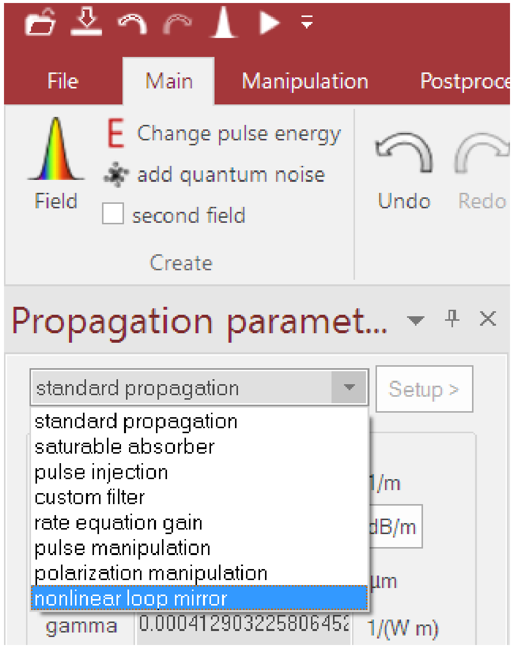
Save this element as testNOLM.ppf

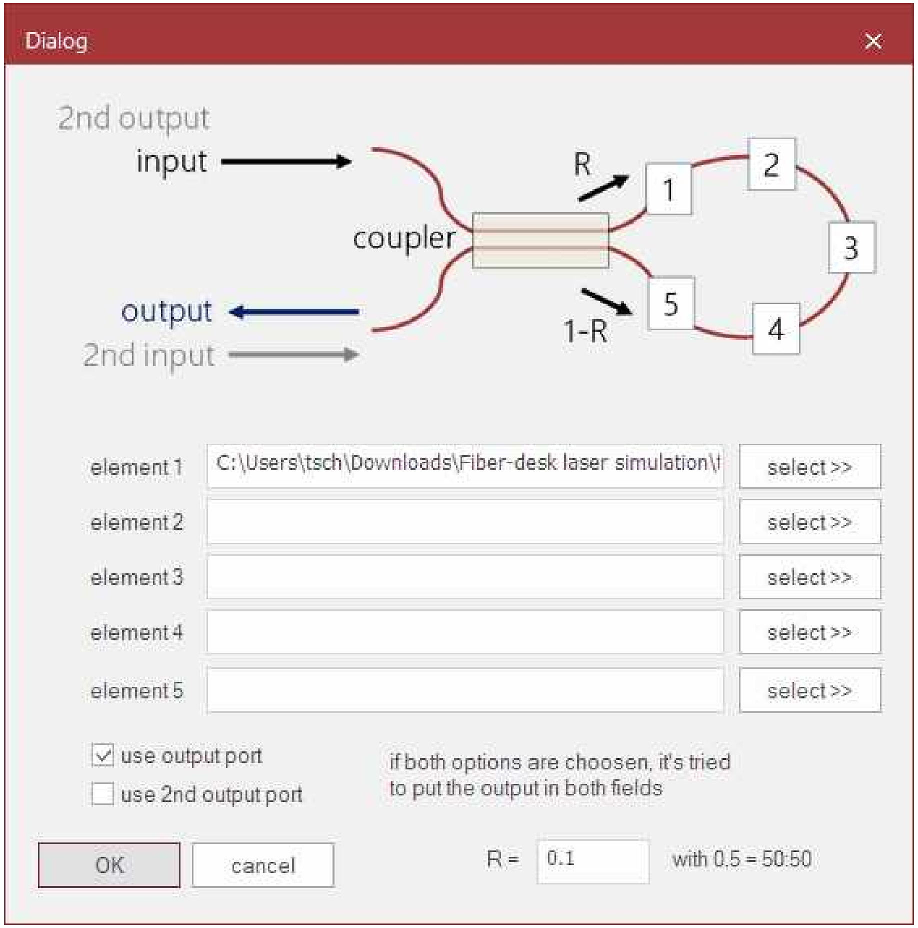


lecture 8

Nonlinear Optical Loop Mirror

Choose the NOLM element and start the setup dialog



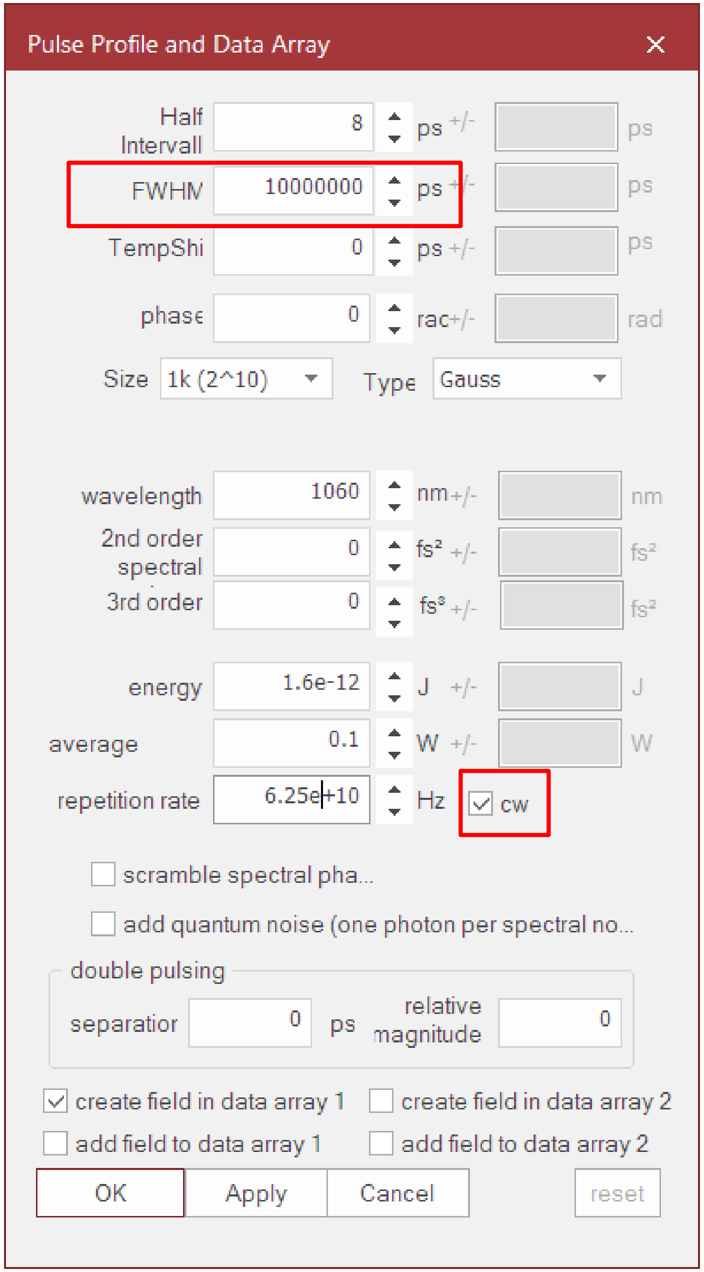


Select the previously saved file for the first element. The output will be the result.

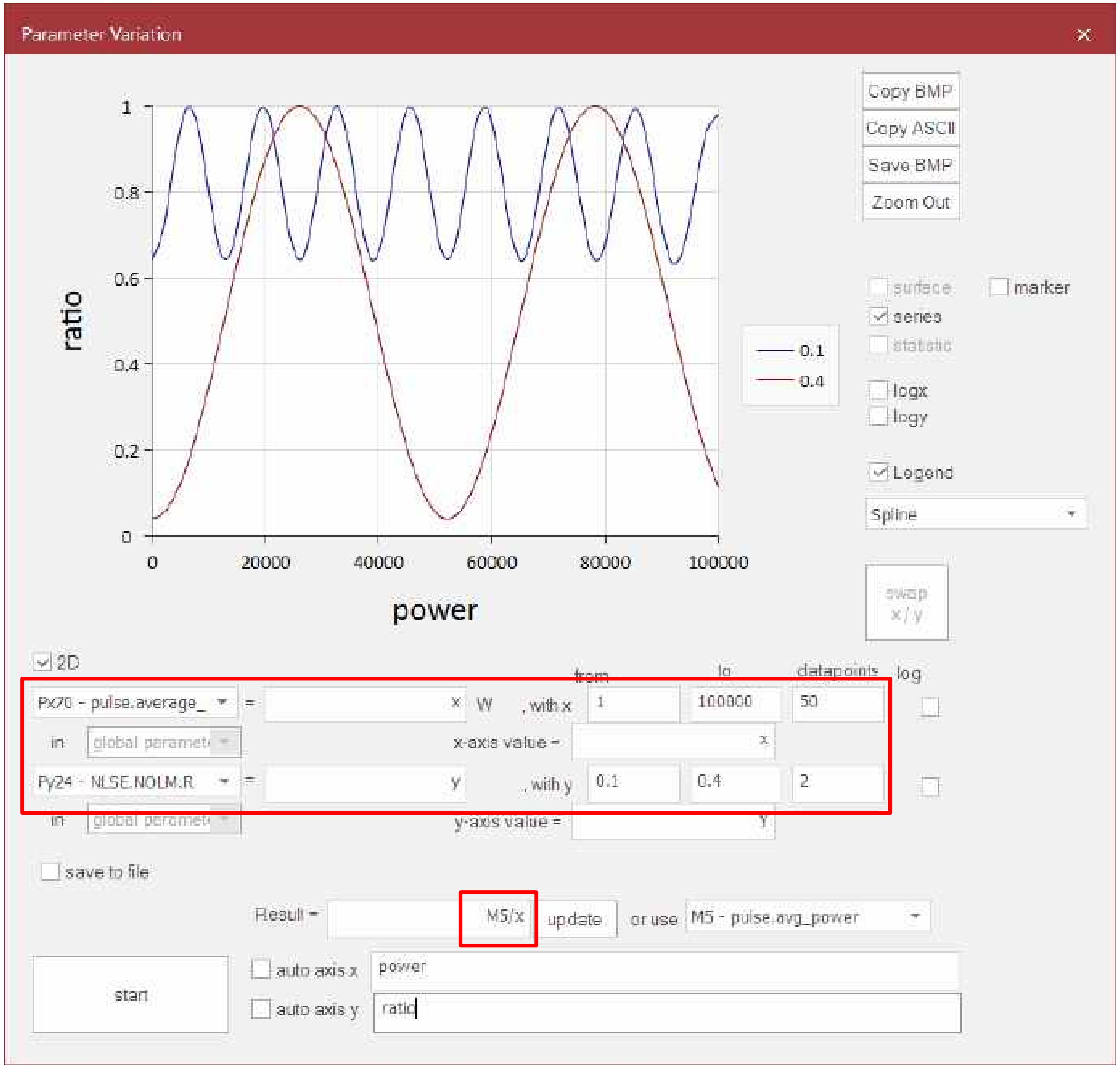
lecture 8

Nonlinear Optical Loop Mirror

In order to see the effect of the nonlinearity in the loop, please define a new pulse as „cw" according to the settings here.



lecture 8



Now the power is varied in the parameter variation dialog as well as the splitting ratio. The displayed results is the output power over the input power.